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SENSATION AND PERCEPTION NUMBER

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CONTENTS

General Reviews and Summaries:

A Critical Review of the Field of Audition: CHRISTIAN A. RUCKMICK, 407. *Functional Relationships in Tactual and Proprioceptive Systems:* MICHAEL J. ZIGLER, 432. *Defects of Color Vision: Their Vocational Incidence and Practical Control; Acquired Defects:* WILLIAM D. TURNER, 448.

Book Reviews: 465.

Books Received: 475.

Notes and News: 476.

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THE
PSYCHOLOGICAL BULLETIN

A CRITICAL REVIEW OF THE FIELD OF AUDITION

BY CHRISTIAN A. RUCKMICK
University of Iowa

This paper constitutes the fifth of a series of critical summaries in the field of audition which the writer has published in a period of a decade and a half (29–32). Since the last of these reviews appeared over five years ago, any attempt to make this survey as comprehensive as the preceding ones would require much more space than is now available. If, as we did before, we include physiological, otological, clinical, physical, and psychological studies, the volume of investigations will be found to have increased almost in a geometrical ratio to the number of years that have elapsed. Although it is rather presumptuous to make a fair selection of outstanding or at least of representative contributions to the subject, such an undertaking may prove much more serviceable than a more detailed and extended review could be.

The extension of activity in connection with the problems of hearing into the fields of the neighboring sciences above referred to illustrates more than ever the artificiality of the boundaries which formally exist between these disciplines and the need for a periodic convention of scientific men interested in these converging investigations. This purpose has been only partially subserved through the establishment and flourishing growth of the Acoustical Society of America, and the stress in that organization toward applied, and especially mechanical and physical problems, does not help to preserve the proper balance between pure science and technology which could be maintained in the type of institute proposed by the writer over a decade ago (28). Since it is therefore neither feasible nor profitable to make a detailed report in this article of the tremendous activity reflected by the published accounts of experimental and

theoretical work done in this area, it will still be possible to maintain a central point of view by citing such typical pieces of research as have contributed to progress in the proper understanding of the auditory function.

Theory of Audition. While we envisaged a remarkable tendency in the period represented by the last review away from the modified Young-Helmholtzian theory of analysis by sympathetic resonance in the organ of Corti and the basilar membrane, or even away from the importance of the anatomical structures of the middle and inner ear, toward a configurational hypothesis involving the cerebral areas, today the tendency is to regard again the basilar mechanism as both suitable and effective in the analysis of tonal sensations. Much is still being written concerning the Wever-Bray effect and many studies are utilizing the technique which was developed in the Princeton laboratory. Results obtained by this technique are frequently interpreted as directly or indirectly implying that with some modifications the auditory mechanism does nothing by way of tonal analysis and everything by way of conduction of the complex sound wave to the auditory (VIIIth cranial) nerve which then transmits this wave by way of the several platforms including the hypothalamus to the cerebral area. What else could such a demonstration mean? Fletcher classifies this type of theory as a 'time pattern' theory because the time pattern is transmitted practically unaltered to the cerebral hemispheres (15). Sounds of speech and pure tones are led into the ear, whether through the pinna and external meatus, or more directly to the middle ear region, and are picked up again by means of a circuit with one lead connected to an electrode which is applied to the auditory nerve and with the other lead attached to an electrode which is grounded in the muscles of the neck. When suitably amplified such spoken words and pure tones can again be clearly perceived by an assembled audience. The assumption here is that the frequencies represented in the original sound-wave are transmitted as such to the brain just as they are transmitted to the ear of the outside listener in the audience. Let us critically survey the evidence.

In view of the fact that investigations on the limits of hearing in the vertebrates immediately below man should be valuable not only from the point of view of determining the sensory equipment of these animals but also for the purpose of supporting some one of the several auditory theories, it is remarkable that so little actual information concerning hearing in the higher vertebrates was at hand at the

beginning of this decade. The reading of Washburn's section on hearing in the higher vertebrates reveals considerable interest in the problem of the auditory sensitivity of these animals, but only a single study, by Jellinek (**23**), concerned itself with the limits of hearing. Washburn concludes that, "the most striking fact about hearing in mammals seems to be that many of them can hear noises but are deaf to tones" (**34**, p. 124).

Since 1930 a large number of studies have used the higher vertebrates as *Versuchstiere* in order to throw light upon the problem of hearing in man. As instances of this type of research, we may regard the investigations which have concentrated their efforts on the function of the round window of the cochlea.

Hughson and Crowe (**21**) have frequently used cats for this form of experiment. The middle ear could easily be exposed in this animal without injury to the tympanic membrane or ossicles. After the tympanic membrane and ossicles, except the foot plate of the stapes, were removed, spoken words and pure tones from various instruments were led to the middle ear, passed on through the cochlea and auditory nerve where they were tapped off by means of an electrode and intensified through a six-stage amplifier to a telephone or loud speaker. Typical of the Wever-Bray technique was the discovery that in the case of more than 75 operative animals, "words or sounds produced at the animal's ear are heard with great clarity and distinctness."

They stated the 3 possible results which experimental lesions may have on the transmission of sound:

(1) *No appreciable effect* may be produced by the puncture of the tympanic membrane and by filling the niche of the round window with wax or plaster.

(2) A *decrease* in the transmission may follow, especially in the case of tones of the lower frequencies, with the fixation of the ossicular chain, division of one of the ossicular joints, and interference with the movements of the head of the malleus.

(3) An *increase* in the volume and clarity of the spoken voice and of pure tones may occur. Such an increase took place in 20 cats when pressure was applied to the round window by means of a soft cotton pledget. This always resulted in marked improvement in the transmission of vocal and all other tones ranging from 512 ~ to 4,096 ~. Although the results were not quantitatively determined they estimated a 50% absorption of acoustic energy for the round window in the normal state. It is therefore considered a sort of safety-valve mechanism for the accommodation to sounds of varying intensity which are normally brought to the cochlea.

In another study (**22**) the round window was closed with a periosteal graft and bone chips after the membrane was punctured with a needle. Introduced tones ranged by octaves from 250 ~ to 8,000 ~. While an increase of 15 to 20 db. above the sensitivity of the normal ear was noted in the region of 500 ~ to 4,000 ~, Hughson and Crowe stated that greatly increased intralabyrinthine pressure has "no effect whatever" upon the transmission of sound.

To test these and similar 'arresting' conclusions, Culler, Finch, and Girden resorted to carefully guarded hearing tests in trained dogs (7).

A stimulus tone of 1,000 ~ was sounded for 2 seconds directly before an electric charge, just strong enough to elicit a positive retraction of the foot, was applied. The dog was thereby conditioned to withdraw the foot as soon as the tonal stimulus began, thus avoiding the electric shock. The tone was then reduced in intensity until the level was reached when the dog began to falter in this conditioned response. When a consistent performance was reached in regard to withdrawal, faltering, and no withdrawal, a threshold value could be obtained over a period of days or weeks which compared favorably in reliability with that of competent human subjects in that the standard error was less than 1 db. In the main experimental series this threshold value was defined "as that stimulus-level which elicits a response in just 50 per cent of all trials." By means of a carefully managed operation, a gum pledget was inserted into the niche of the round window. The pellet of gum was enclosed in a gauze mesh to which threads were attached so that the plug could be readily withdrawn without anaesthesia. Only 15 minutes elapsed between tests with plugs in and with plugs out. It was found that in these 11 trained dogs the insertion of the plugs impaired hearing from 7 to 31 db. and that withdrawal of the plugs was accompanied by restored auditory acuity. The mean difference in scores was almost 10 db. The experimenters suggested that damping, weighting, or immobilizing the round window or secondary tympanic membrane "definitely impairs the efficiency of cochlear function."

To account for the remarkable discrepancy between their data and those of Hughson and Crowe, they offer the criticism, with which the writer agrees, that "the acoustic significance of a given phenomenon or effect can be demonstrated only by actual tests of hearing" and that "such acoustic value cannot be assumed or inferred merely because that phenomenon or effect has been observed in connection with the middle ear, cochlea, or eighth nerve." With the increasing tendency to resort to physiological principles in experimental psychology frequently goes the unguarded assumption that physiological determinants are psychological data, especially in view of the fact that physiological or biological measurements often represent extreme care and accuracy of technique and are therefore all the more misleading in this regard. It is the proper psychological inference that is then important. Electrical acoustical manifestation by no means indicates mental auditory sensation.

By a similar technique Culler, Finch, Girden, and Brogden (8) have obtained significant measurements of auditory acuity in dogs and cats. They point out the value of this CR technique in comparison with results obtained on human subjects and presumably as a

distinct improvement over meaningless physiological and biological techniques which reveal little by way of actual hearing. An electric shock is stepped up until it arouses an adequate conditioned response to the tone and then it is utilized later as an indicator of hearing. A number of difficulties involved in the refractory period, in over-activity and underactivity, especially in the post-operative period, and in reënforcement through the substitution in the treatment of results, seem to have been satisfactorily met.

An analogous subject which offers contributions to auditory theory is that of auditory adaptation or fatigue, especially when the investigation of such phenomena is directed toward specific regions of pitch. Thus Pearce (**27**) followed Pattie's technique of using both ears, one of which was fatigued to a tone of a given frequency, while the other was stimulated only occasionally to obtain comparative judgments. Two tones were made nearly equal in intensity and the apparent increase in intensity of the tone directed to the previously unstimulated and therefore unfatigued ear indicated the relative amount of fatigue of the second ear. The duration of fatigue after 45 seconds of stimulation could be measured by the time taken for the judgments of 'louder' to return to the normal percentage. Four judgments were recorded at 0, 10, 20, and 30 seconds after the cessation of the continuous tone. Weinberg and Allen had obtained results which they assumed as corroborative of the resonance theory of hearing, namely, that the rate at which a tone must be interrupted in order to obtain a just continuous sensation is lowered by previous stimulation for 2 minutes by a tone of that pitch. Between 142 ~ and 285 ~ the effect was decreased if the adapting tone was of slightly higher or lower pitch, and if the prolonged tone differed in pitch from the tone measured by more than 15 ~ no adaptation occurred. Pearce found, however, that pure tones less than 1,200 ~ in pitch tend to have more effect by way of adaptation on tones of other pitches above and below than do tones above 1,200 ~ in pitch. Below 800 ~ adaptation almost always occurs. The effect is also accentuated if the stimulating or fatiguing tone is of the same pitch as the affected tone. Prolonged stimulation by tones of low pitch has a more marked effect than that produced by high tones. While the experimenter was more interested in perfecting techniques of the type used, he concluded that the results with low tone were more in accordance with a 'time pattern' type of function of the cochlear mechanism. Since, on the other hand, the higher tones behaved more in accordance with a 'space pattern' of function, he compromised by his

willingness to accept both types of function within the bounds indicated.

Békésy (3) had already claimed that tones are not fatiguing in a uniform manner. According to a modified Helmholtzian theory involving regional analysis in the basilar membrane, he proved that what theoretically should happen, did happen: lower tones sounded lower and higher tones sounded higher than the fatiguing tone. He went on to claim that the basilar mechanism can be set into action through a type of osmosis giving rise to a chemico-electrical stimulation of the nerve cells by means of a concentration of the perilymph in whirling formations. Békésy therefore definitely argued against a telephone or 'tonal picture' theory (really a form of time pattern) and in favor of a spatial pattern on a membrane that is related to the cutaneous membrane and contains a sensory mechanism for pressure. In this case the pressure is hydrodynamic and leads to an electrochemical change in the density of the tissues about the nerve cells.

Such investigations lead to the more marked controversy which has developed about the problem of 'stimulation deafness.' Horton (19) recited the commonly reported data which show that low tones tend to destroy the basilar structures of the cochlea near the apex and that high tones conversely destroy the corresponding tissues near the basal region. Often, however, investigations have revealed a fairly general destruction of the organ of Corti ranging from one-eighth to more than three-fourths of the whole length of the cochlea. As the results varied, now the resonance, now the telephone theory came in for support.

With guinea pigs as subjects Horton used a breathing cue as the means of detecting hearing. Tones from 64 ~ to 8,192 ~ were passed through a special 12 v. speaker whose moving coil opened and closed a series of slits allowing air at 7 pounds' pressure to escape in a sound-proof room where the animals remained. This gave out tones at 125 db. above the human threshold. The experimenter could not remain in the room for more than a minute or two at a time even when his ears were stuffed with wet cotton, whereas the animals were confined here for 10 hours at a time on 11 successive days. A series of 5 tests, the last of which occurred 298 days after the treatment, indicated that there was a general loss of sensitivity with no subsequent recovery of hearing. In another case Horton (20) applied a 1,500 ~ tone on 8 animals and a 3,000 ~ tone on 4 animals at 100 db. intensity above the normal human threshold for a total period of 2,000 hours and 1,250 hours respectively. Contrary to other reports there were no symptoms of fear in these guinea pigs after the experiment was begun, and adaptation to the situation occurred within a few days. When tested in 8 octave steps from 64 ~ to 8,192 ~, also for the specific tones of 1,500 ~ and 3,000 ~ on the respective groups, a general loss of hearing and no recovery were found.

Historically a curious reversal has occurred. For many decades in the early days of experimentation on pitch discrimination no control was exercised over the accompanying intensities of the tones tested. Now that it is standard practice to control the intensities at which pitch frequencies are applied, intensity has arisen to overwhelm and devour pitch! But to the reviewer the above findings also represent a curious reversal of the logic which underlies the inferences that are drawn from the experimental data. To the writer's knowledge no physiologist has argued that because ethyl chloride in small doses is sensed as olfactory sensation, because then in increasing amounts it gradually eliminates all types of sensation, and because it finally renders the *Versuchstier* unconscious, the various sensory organs in their original normal condition are not selective in their sensitivity! In other words, a bombardment by tones of such great intensity can be followed only by a pathological function and ultimately by a structural change from which few, if any, deductions can be made as to the normal state of affairs.

Lurie and his colleagues (**10**) have succeeded in showing that, when the stimulation deafness was varied, by examining the cochlear damage and the functional electrical responsiveness of the cochlea of a guinea pig under different amounts of prolonged stimulation, a varying amount of damage was discovered in the structures on the basilar membrane.

After finding a normal threshold of auditory acuity within 10 db. of the human threshold for tones between 60 ~ and 1,500 ~ and a lower threshold by about 20 db. for tones from 2,000 ~ to 10,000 ~ by means of electrical techniques, they were able to check these values within the usual experimental margin of error when tested by means of the CR method. When cats and guinea pigs were subjected to prolonged stimulation at loud intensities lasting for 75 days from 16 to 24 hours per day at 60 to 95 db., fairly extensive damage was detected in the organ of Corti with a stimulating tone of 2,500 ~. Continued exposure to a tone of 2,500 ~ at 95 and 105 db. for a shorter period caused the hair cells in a considerable area of the basilar membrane near the second cochlear whorl to show extensive deterioration. The inner cells of the external group were seen to have been most violently mechanically agitated and the internal group were the least injured.

The experimenters conclude that all the evidence points to the fact that the hair cells of the organ of Corti are the important end-organs of hearing in the sense that they are necessary to complete the electrical response; that the basilar membrane or the cochlea does not respond uniformly as a whole; and that auditory theories of the resonance type should be conceived as 'zone' theories rather

than ' place ' theories, since an extensive zone appeared to have been destroyed or injured even with less than maximal stimulation. The writers also point out that the mechanism is a highly damped system and must not be considered as a freely vibrating mechanism. In another report (9) these experimenters had already stated that the zone of greatest loss in auditory acuity as electrically determined does not generally agree with the stimulating tone in frequency. When the damage is moderate in extent the evidence supports a space pattern theory rather than a time pattern theory.

The importance of the cochlear mechanism, especially that of the organ of Corti, is brought out by these workers (24) in pathological cases. The cochlear response disappears when the organ of Corti is not present or is structurally incapable of functioning and reappears in cases where the organ is normal. Electrical nerve impulses were never discovered in the absence of cochlear responses, but they may disappear in the presence of normal cochlear activity. They have also shown (11) that the plotted amplitudes of the curve obtained from the cochlear response correspond fairly closely to those secured from the eighth (auditory) nerve over a large range of frequencies. Probably the electrical disturbance in the cochlea functions in setting up similar impulses in the auditory nerve. These correspond to the frequencies of the cochlear fibers up to 1,000 $\sim$; after this point the fibers respond to alternate frequencies and thereafter in increasing ratios up to the higher frequencies.

A vast amount of conflicting clinical and experimental data is contained in a symposium held last year (1935) before the American Otological Society at Toronto (44). Space again forbids extended treatment. Techniques reported varied considerably and pathological findings frequently defy careful diagnosis and scientific analysis because often even when the post mortem examination of the cochlear region presents astounding atrophies, the progressive degeneration of the organs involved has not been carefully checked up to the moment of death. Intracranial conduction of tones to the better or intact ear and the masking of tones heard in the separate ears are often inadequately taken into account. A selection of what seem to the critical reviewer to be the more significant reports invites the charge of bias and prejudice. At the risk of such an accusation, however, some of the more thorough-going and cautiously pursued investigations are included in this summary.

Among the clinical and post mortem studies which bear on the several theories of audition are those of Bunch and Wolff (44,

pp. 19–36). Although cautiously stated, the conclusions reached stand in favor of the possibility of some form of hearing without the functioning of the organ of Corti. Sometimes, it is admitted, the fatal disease was of such a wasting character that it was not clearly demonstrable just what progressively happened in the interval between the recorded audiogram and death, even when the post mortem examination was undertaken as soon as an hour or so after death. But the authors declare that their findings " are in agreement with those of certain earlier investigators who found that hearing [usually of considerably reduced sensitivity] was possible in the absence of the organ of Corti." Hughson, Thompson, and Witting (**44**, pp. 42–57) go farther by stating that " though the apex [of the cochlea] is doubtless necessary for optimum experimental transmission or clinical perception of tones, any intact portion of the end-organ may serve as the receptor of a stimulus of low frequency applied to the ear." In the discussion of these and other clinical reports, including their own findings, both Goldstein (**44**, pp. 87–89) and Fowler (**44**, pp. 89–102) are satisfied that localization of sound frequencies on the basilar structures, as a space pattern theory would require, has not been disproved. The former points out that the Wever-Bray effect, startling in its results and widely applied as a technique as it has been, is taken from the auditory nerve as a whole. Guild and others have pointed out (**44**, pp. 15–18) that in the bundle of fibers representing that nerve trunk, " the fibers from the basal turn form, in general, the outer layer of the trunk of the cochlear nerve and those from the apical turn are near the center." Goldstein states that " a lack of synchronism in the different fibers will produce interference of the potential waves." Any probe or electrode inserted into the nerve as a whole would not be able to take off energy from the separately conducting paths, but would represent merely a differential loading among the various fibers. It could then not be used to controvert the Helmholtzian position as to the possibility of a modified form of sympathetic resonance in the basilar structures. Fowler summarized the situation in terms of the clinical evidence by stating that even in the absence of definite correlations between basilar localizations and tonal frequencies, especially in the region of low tones, there is found no " valid reason for believing that there is no localization." The pick-up from the basilar membrane may be dependent on some physical principle other than localization, but the basis may be there nevertheless. Obviously the simple analogy of sympathetic resonance as applied to the strings of a harp is inadequate when

applied to such a complicated hydrodynamic structure as the cochlea with all of its ramified appurtenances and the possibility of obstruction setting in through disease or experimental manipulation in these various normally balanced parts.

Bast and Eyster (**44**, pp. 57–68) also point out that the Wever-Bray effect was originally conceived as an action current in the auditory nerve, but that it must now be clearly understood as an electrical impulse, picked up in the formation of a differential potential separate from the action current, and due to the reception of sound in the cochlea. The data secured from 70 guinea pig ears, when the cochlea was electrically tapped at several levels, when it was punctured, and when it was partly removed, show that (1) cochlear currents developed in response to sound stimulation depend upon the maintenance of certain pressure relations across membranes in the cochlea; (2) localization, which is not absolutely specific as to frequency patterns, does occur in the cochlea, low frequencies being more readily picked up from the apex and high frequencies from the base; and (3) integrity of the cochlea is not absolutely essential to the production of the electrical response in the guinea pig, but extensive pathological changes which interfere with the balance of membranous pressures radically reduce conduction of sound and consequent electrical manifestations.

Turning now to the experimental work on animals, the symposium reports the work of Davis, Lurie, and Stevens (**44**, pp. 41–42) who picked up the electrical potentials produced in the ears of guinea pigs with electrodes placed on the round window and the neck. The current was studied by means of a cathode ray oscillograph. The cochlea was drilled at various levels, producing a loss in hearing of 20 to 30 db. High tones were definitely localized near the base of the cochlea and low tones were bunched more closely at the apex than had been previously supposed, while tones of 2,000 ~ were distributed in the middle region. A considerable spreading effect of the tone on the basilar membrane is noticeable when the intensity is increased 20 to 30 db. above the threshold. Localization on the basilar membrane closely resembled that found in human subjects.

Culler (**44**, pp. 72–78) outlined the chief techniques for approaching problems of hearing only to show that while the 4 methods, stimulation deafness, introduction of drugs into the cochlea, mechanical lesions, and scorching with an electric needle, have been of value, the conclusions drawn from the data did not always take into account the abnormal condition of a delicate hydrodynamic system

that has been even ever so slightly tampered with. He therefore preferred to work with an intact mechanism, but used the Wever-Bray technique in spite of the fact that he usually proceeded with more direct tests of actual hearing. The electrical method proved to be " more simple and direct."

The cochlea of the guinea pig, having 4 to 4½ turns is unusually accessible. Therefore the auditory structures from tympanic membrane through the ossicles, cochlea, and auditory nerve were not mechanically molested in any way. At 24 different critical points in the cochlea an electrode, consisting of a sharp tungsten wire and covered with a film of oil to minimize condensation of atmospheric moisture, was applied in turn. The oscillator was set from series to series at the following frequencies: 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 5000, 6000, and 7000. Before reaching the speaker the electrical input was conducted through an attenuator by means of which the intensity could be controlled from 1 to 127 db. The electrical output from these various points on the cochlea, to which the electrode was successively applied, was transmitted through amplifiers into a tube voltmeter from which the results were read. Only minimal intensities were used because that procedure is similar to that used in investigating limens of hearing in human subjects and produces the least disturbance in the mechanism. Both the introduction of a 'spread' in the basilar membrane structures and the excitation of upper partials is thus avoided. The input intensity was thus increased until a given amount of deflection was produced on the voltmeter, which amount was arbitrarily chosen as the liminal value.

In terms of this procedure Culler obtained data that fairly clearly indicated limens of response at certain critical points in the cochlea. The margin of error in the various readings was no greater than that commonly found in experiments of this type, the greatest possible error in cochlea location being 10% to 12%. The result was that each frequency within the audible range was found to have " its own focus of response within the cochlea." An accompanying chart gives these foci for the frequencies above enumerated. The higher frequencies were located near the base and the lower ones were crowded near the helicotrema. A substantial agreement was thus discovered with the work of Stevens and Lurie, and an additional well controlled support was given to some type of place pattern theory rather than to a time pattern theory. Again the mechanism which provided this electrical response was not revealed, but if the hypothesis be accepted that physiological functions are generally accompanied by electrical phenomena, or better still that physiological functions are of an electro-chemical nature, then an electrical response maximally manifested in a given locality would strongly indicate a physiological

function of the same order of intensity. Under the circumstances no other kind of reaction could explain these phenomena.

In closing this section on auditory theory we may stress the facts (1) that a very large degree of interest has centered during the last half decade in the problem of the type and place of response to be found in the hearing mechanisms, (2) that in the great frontal attack on this problem an unseemly but absolutely unavoidable confusion exists in the interpretation of results, but (3) that from the better controlled techniques which least interfere with the normal functioning of the auditory mechanisms it appears that some form of space pattern theory would best interpret the discovered data.

How contradictory these results are in terms of the original claims by Wever and Bray may be gathered from reading their earlier publications (**40**). Tones were led into the external meatus of 18 cats which had been decerebrated and an electrode was brought into contact with the auditory nerve along the short stretch of a few millimeters after it leaves the internal auditory meatus and enters the medulla. The other negative electrode was fastened into the muscles of the neck. Amplification of the signals from 320 times to about 100,000 times was provided for. Tones and speech were thus transmitted to a telephone or loudspeaker and were received with such fidelity that the person in the sound-proof room could often identify the speaking individual. The experiments were checked physically and physiologically with the result that these electrical responses could be interpreted only as action currents from the auditory nerve and the response has been repeatedly so named (**39**). The data indicated that the basilar membrane could not be selective in an analytical way, but that the total frequencies were being transmitted through the auditory nerve to the brain.

In the face of such results Fletcher (**15**) reviewed the two types of theory. In one case sounds existing as a time pattern in the transmitting medium become translated into a space pattern on the basilar membrane. Among such space pattern theories falls the Young-Helmholtz doctrine. Then there is the possibility that the time pattern remains untranslated and is transferred as such over the auditory nerve to the brain. This is what is supposed to happen by many who are using the Wever-Bray technique. Fletcher proposed a combination of these theories by suggesting that the pitch of any tone is determined both by the place of maximal stimulation on the basilar membrane, which is the more important principle for high tones, and by the time pattern sent directly to the brain, which is the

more important principle for low tones. Intensity is construed as equivalent to the number of nerve impulses reaching the brain per second and probably depends somewhat on the extensity of the stimulated patch. The latter is responsible for the psychological attribute of volume or extensity, and 'brightness' is the correlate of the sharpness of the peaks in the vibrational or time pattern form, as suggested by Troland. Both ears together then secure 4 space patterns, each one also carrying some form of the time pattern. Recognition of the frequency of the stimulating tone thus takes place in the cerebral areas.

Wever (**38**) has recently lent his support to such a compromise which he called the 'resonance volley' theory. After a thoroughgoing review of the historical literature on the subject he meets the difficulty concerning the responsiveness of the basilar fibers to very high tones, as revealed in some studies, by suggesting that a large number of fibers with various refractory periods could produce a volley which would be relatively out of step but synchronous with the stimulus. Thus 40 fibers responding at the rate of 500 per second would provide the upper values up to 20,000 ~. The refractory phase would thereby be a help rather than a hindrance to auditory theory. Since the highest allocations which Culler has obtained at the basal end of the cochlea were in the neighborhood of 7,000 ~, and since this point was situated a little more than one-eighth of a turn from the base, the remaining octave and a half could hardly be crowded into a space pattern on the cochlea. In this region octaves are separated about 180°. Important considerations concerning the tension, loading, and length of the basilar fibers are also generally held against the possibility of a true resonance principle as operative here, even when allowances are made for such newer concepts as osmotic pressure in a damped hydrodynamic system.

From all these data the reviewer believes that for some time to come the clinical, experimental, and normal occurrences of hearing will very likely be construed in terms of a modified Young-Helmholtz interpretation. Békésy's notion of some sort of osmotic pressure functioning at the regions of the basilar structures which are sympathetically thrown into response through the differential hydrodynamic condition between the perilymph in the vestibular and tympanic canals and the endolymph in the cochlear canal, but without the necessity of producing either eddies or whirls as Békésy believed, might cause the electrical phenomena to appear when the nerve endings in the hair cells are thus stimulated. The relatively high

thresholds of hearing at both ends of the cochlea could be explained in terms of the fact that at the helicotrema or apex these long waves would produce a relatively small differential pressure on both sides of the cochlear canal. Naturally with so minute and complex a structure as the cochlea we need not apply simple equations of velocity or hydraulic pressure. From the tympanic membrane on we are faced with the intricacies of a moving chain of ossicles whose tension and position may be reflexly varied by the tensor tympani and stapedius muscles. At the end-plate of the stapes the energy is translated into hydraulic displacement of a complicated type, because the enclosed perilymph is entirely confined within the cochlea whereas the endolymph in the cochlear canal has an outlet into the saccule. Ultimately the entire lymphatic system is confined within the bony walls of the skull, the only elastic outlet being the membranous round window. Furthermore this cochlea is a tightly wound-up pathway to this energy and is doubled up upon itself. Therefore no ordinary quantifications of energy are applicable.

On the other end of the cochlea, namely at the base, we may have to resort to a radical departure from the space pattern theory and follow the suggestions of Fletcher, Troland, and Wever. The volley effect of fibril response might here be taken into the picture and be made to do service where the higher frequencies, not commonly used in speech or everyday life, are involved. At this place we may have to pass to a time pattern or frequency theory, which does not mean, however, that the fibers transmit to the auditory nerve just what they receive. The refractory phase allows a new type of response to occur which, when transmitted into electro-chemical activity, gives a suitable medium of differentiation. The explanation of the function of the inner ear is therefore not a simple one. On the other hand we must marvel at the persistence of some form of the Young-Helmholtzian principle in spite of vigorous attacks and counter-proposals.

In fine, we may say that the collective evidence obtained under the better controlled conditions points to several negative conclusions.

1. The mechanisms of the middle and inner ear do *not* simply transmit sound energy to the auditory nerve.

2. The cerebral auditory areas or any other cerebral areas are *not* called upon to do the major work of tonal analysis.

3. The electrical energy picked up from the auditory nerve is *not* equivalent to the electro-chemical response which is normally cor-

related with auditory sensation in either the physiological or psychological meaning.

4. The Young-Helmholtzian theory of sympathetic resonance, when properly modified and supplemented, has *not* been scrapped.

Hearing in the Lower Animals. While many of the investigations above referred to have utilized the lower animals as subjects, the bearing of the data was directed more to general auditory theory than to the discovery of facts concerning hearing in these animals. Of course, from the comparative point of view, there is never any discontinuity of facts. But there is a discernible shift of emphasis. One of the reasons for a considerably increased productivity in this special field lies in the bearing that facts found in the lower animal ranges have upon auditory theories as applied to man. Another cause can be attributed to the greater interest in developing dependable techniques for obtaining evidence of actual hearing. For example, we must distinguish the conditioned response techniques from the Wever-Bray electrical response techniques. In the former case the animal is trained sometimes for a period of 3 weeks before discriminations as to pitch or intensity are recorded. In the case of a dog an electrical shock of reduced intensity is given to the dog with the tone, usually a standard tone of 1,000 ~, as noted above, and then the withdrawal of one of the front paws, when the tone is given without the shock, is taken as the indicator of hearing. That this signal cannot be accepted as the complete auditory response in the form of a psychological sensation or perception on the level with human experience, has been demonstrated by Culler himself who has developed this technique. After he had spooned out the cerebral cortex of several dogs, with the auditory area therefore entirely destroyed, the dog still gave the conditioned response of contracting the entire body when the sound occurred without the electrical shock. It may be, however, that there is a vast difference between this type of contraction or spasm and the more delicately coördinated pawing which Culler and his colleagues use as evidence of conscious hearing.

Another method is reported by Horton. The animals, which are usually guinea pigs, are strapped into a cradle after they have had an extensive period of training during which the respiratory response has been conditioned to tones and shocks. When the shock is removed and only the tone or other sound is given, the 'catch' in the respiratory curve as photographed in the sound-proof cage is taken as the indication of hearing. Undoubtedly this is a safer sign

of hearing than the Preyer reflex (a twitch in the pinna in response to sound), but even so, Upton and Wever have suggested that the respiratory change may be of an emotional or affective category, rather than a sign of hearing. Since again this type of conditioning is likely to become subcortical, there is no clear indication that hearing as such has occurred.

Then there is the Wever-Bray electrical response technique which is still undergoing appraisal as to just what it signifies. Several investigators deny that this electrical response is of the order of an action current, and Wever and Bray no longer call it by that name. Exactly what the correlation between this auditory nerve response and hearing is, still remains in doubt, although Lurie and his colleagues have shown that the electrical cochlear response pattern in terms of audiograms corresponds very well with the electrical response from the auditory nerve. Therefore when this technique is used in the case of lower animals, we can only say that this response has been found; we cannot be absolutely sure that hearing has occurred.

On the basis of discrimination-box methods Maier and Schneirla (**25**) point out that mammals appear to have poor hearing whereas the CR methods reveal rather good hearing. These authors feel, however, that tonal hearing becomes dominant only in the primates: below this level tonal hearing, as Washburn recorded in an earlier treatise, is much less significant.

In the light of such summary remarks it is interesting to note what has been revealed by the Wever-Bray and other techniques. Wever and Bray (**42**) studied hearing in insects such as the crickets, katydids, and grasshoppers. They found that whereas in the cricket the oscillator delivered frequencies from 32 ~ to 50,000 ~, the electrical responses from the termination of the nerve fiber in the cell body on the embedded end of the tympanal organ recorded a range of 300 ~ to 8,000 ~ in some cases and 430 ~ to 25,000 ~ in others. A number of other sources of tone were also tried. One katydid responded with a range of 800 ~ to 45,000 ~. In all 3 katydids the responses seemed definitely more intense to tones in the range from 30,000 to 35,000 ~, which is, of course, much higher than the upper limit for man. They investigated the source of these electrical phenomena but were not sure whether the responses came from the sensory or ganglion cells within the end-organ or in the fibers of the tympanal nerve. The writers conclude, however, that the response originated within the tympanal organ, or in some cases

indicated nerve impulses. Some of these appear to have occurred also reflexly in the motor nerves, especially in the crickets.

In the decapitated grasshopper Wever (37) found that the tympanum, which is here located on the first segment of the abdomen instead of the tibial segment of the foreleg, was very insensitive as compared with the human ear. With his technique he used 95 db. as the threshold, which is 30,000 times that of the human ear. Maximal sensitivity occurred at 10,000 ~ as compared with that of 1,500 ~ in the human ear. Responses were obtained within a range of 300 ~ to 21,000 ~. Since only 3 readings were taken at each frequency, the results cannot be positively stated.

Even the turtle has been investigated by this technique. Wever and Bray (41) found that the responses to noises and low tones were excellent and showed greater sensitivity than in the case of mammals. Above 500 ~ the electrical response declined rapidly in intensity and became inaudible at about 1,200 ~. The complete removal of both tympanic membranes destroyed the response which was restored, however, if the sounding instrument were placed in contact with the bony structure of the skull and thus utilized bone-conduction.

One of the valuable contributions of this period is the study of auditory acuity in the chimpanzee by Elder (14). The author quotes Yerkes and Yerkes to the effect that, in spite of notable work in other directions in 1932, our knowledge of "this animal's hearing is virtually a *terra incognita* to the psychologist." Wendt found that acuity audiograms for monkeys correspond closely to those obtained from human subjects in the range between 64 ~ and 8,192 ~. Working with 3 chimpanzees Elder used an audio-oscillator giving the same range of frequencies with an attenuator control of intensities ranging from −20 to +95 db. in steps of 5 db. When the animal heard the sound he pressed a key which gave him access to food. Most of the training concentrated on the problem of not pressing the key when no sound was given. With the exception of the averages for a frequency of 4,096 ~ in the case of 2 animals, all of the thresholds were found to be slightly lower than those of human subjects. Making allowance for certain errors, the investigator believes that the hearing of chimpanzees closely resembles the hearing of younger human subjects.

Under somewhat similar conditions Wendt (35) found that his monkeys were equal in auditory acuity to humans in the range of frequencies from 64 ~ to 1,024 ~; they were slightly inferior at 2,048 ~, markedly inferior at 4,096 ~, and superior at 16,384 ~. From 4,096 ~ to 8,192 ~ his results were comparable to those of Elder.

Many more studies could be cited and reviewed to show that the Wever-Bray technique has opened up some new possibilities in the area of investigating auditory capacities in the lower animals. In almost every case light is thrown on the various forms which modern auditory theories are taking. At the same time new facts are emerging concerning animal hearing. Without doubt techniques which make more certain what kind of 'hearing' we are dealing with are also being tried out and perfected as a contribution to methodology in animal experimentation. In closing this section we may call attention to the tentative conclusion that noises seem to predominate in the lowest animal forms as stimuli to activity, with the rather surprising result that insects like the crickets and katydids are sensitive to very high notes if we accept the electrical responses as indicative of hearing in the traditional sense. Then among the reptiles, again by means of this technique, we find that low tones are more effective in terms of the threshold, whereas monkeys come most closely to human subjects in their responses. From the methodological angle we may safely assume that some form of CR technique, especially if it involves a response by means of a group of voluntary muscles, is a much more likely indicator of actual conscious hearing. Even here we must guard against 2 opposite extremes: on the one hand this voluntary response can become of the order of a secondary reflex and be therefore subcortical in origin, or it may become too elaborate, as in the discrimination-box situation, in which case we may be getting responses to perceptual patterns. Under those circumstances we are moving away from the typical experiment on human subjects who are called upon to make simple judgments to more or less sensory data. In the present state of scientific supersensitiveness concerning the danger of drawing conclusions from one set of conditions and making them apply to situations involving other sets of factors, it is wiser to withhold analogies until much more information is at hand concerning the problem of auditory acuity and pitch discrimination in specimens taken at intervals along the line of progress in the evolutionary development of animals. We can easily note, however, that there is a renewed interest and vigor of research in this area, with finer instrumental and technical approaches and greater care in the evaluation of results than has ever before been evident.

Sound Localization. Still more encouraging is the renewed interest that has appeared in the problem of sound localization. Three of the 17 papers, which were contributed to a discussion of audition before the Physical Society of Great Britain, concerned

themselves with this subject. Banister (**43**, pp. 104–113) reported 3 established facts: (1) sound localization is a binaural effect, (2) judgment of distance is an extra-auditory function, and (3) judgment of the altitude of sound or whether it is in front or behind the hearer is also an extra-auditory function. Among the binaural and therefore strictly auditory factors are intensity, phase, time, and possibly 'volume' in the technical sense of voluminousness. His own theory of sound localization is defended in this article in view of the additional experimental facts. It briefly centers on a supposed tension of the cilia of the hair cells whose tips are imbedded in the tectorial membrane. When the basilar membrane of which they are a structural part is agitated, the nerve impulse will be generated. There is a time lag between this agitation and the vibration of the air in the external meatus. In the absence of a scientific measurement of the refractory period of the auditory nerve fibers, he assumes that it is of the order of 2σ. Under certain conditions then the basilar membrane will not respond to any other frequency but a given one for which at that moment the hair cells are under tension. Correct localization will take place only when the same wave in the air is the effective wave for each ear. This 'time difference' effect may be supplemented by the intensity effect especially for those higher frequencies for which the head itself forms a definite shadow.

Tucker (**43**, pp. 114–119) showed that under certain conditions localization can be made by sound intensity monaurally or with the ears so oriented that no phase difference is possible. This can be achieved through the use of stethoscopes with trumpet or horn orifices. The movement of the trumpet forms a direction-finder according to a decibel scale which is calculated. The added advantage of the Rayleigh double disc as an accessory to the direction-finder is also discussed. Von Hornbostel (**43**, pp. 120–127) gave three factors which have been discussed in the perception of hearing: wave-form, intensity, and time or phase. He eliminated wave-form because microphones can be substituted in place of the 2 ears without changing the perception of direction. He argued that intensity differences cannot be converted into time differences and should not even be considered as supplementary to the latter, which has been accepted by most authors. The time factor may be ultimately reduced to a motor response of the order of a tropism, so that the time-lead may result in a reduction of a state of tonicity to that of equilibrium.

In a novel type of attack Holt-Hansen (**18**) has determined the fact that if observers are asked to tell at which point between the median plane and the aural axis the quadrant is equally divided, the results seemed to show that 30° from the median or sagittal plane is equated to 60° for the rest of the quadrant. In other words, while

blind-folded, observers were asked to state when a third clock sounded equidistant from 2 other clocks which were placed immediately in front in the median plane and in the aural axis respectively. When the observers were asked by means of the method of minimal changes to report when the middle clock, used as the variable, seemed to have made an angle 3 times as great from the clock in the median plane as it was from the clock in the aural axis, the resultant experienced angle turned out to be equal to 45°. The results he interpreted as substantiating the time theory of sound localization advocated by Von Hornbostel.

Trimble (33) undertook "to clarify and extend the experimental facts bearing on the relative rôles of intensity-difference and phase-difference in binaural localization." The study involved 3 sets of conditions: (1) independent control and introduction of these 2 factors, (2) opposition in the function of the 2 factors, (3) reënforcement of the function of the 2 factors. He found that under the first set of conditions localization is less clear and definite for dichotic phase than for dichotic intensity, and that phase differences are effective only in a limited range of the lower frequencies with an upper range of 1,250 ~ to 4,000 ~, depending on the observer. The phenomenal sound produced by dichotic differences of phase tends to be more complex than that generated by dichotic differences in intensity. Intensity differences were more effective for the localization of the phenomenal sound as a whole than were phase differences. These conclusions were further supported by the series of experiments in which the 2 factors were opposed. Each one is characteristically effective, but they tend to minimize the influence of each one separately when they are operating together in the same direction. As a net result intensity differences seemed to outweigh the phase differences in the judgment of sound localization.

Such a telling result with trained observers under controlled conditions appears to upset the theories of many authorities in this field. Of course the conditions of the experiment were rigorously set and differed in some aspects from those of previous experiments, but such criticisms as those involving laboratory atmosphere and bias on the part of the experimenter are from the reviewer's knowledge definitely out of the picture. The answer to the rather surprising results seems to lie in the direction of pointing out the extremely complex situation which converges on the individual in everyday life when he is localizing sounds under natural conditions. Tones are usually very com-

plex in clang quality and many other sounds are noises. The binaural ratio is then a ratio involving a pattern difference in which the time factor may still be an influential component. Biologically considered, especially since it is plausible to think of the lower animals as being more responsive to noises than to tones, the intensity factor should be the more important one on the basis of which bodily orientations have been built up. In the complex disturbance of a noise, phase and temporal relations are out of the issue. Since also the head is usually in a mobile condition, the effect of sound shadow on even the higher frequencies is fairly well eliminated. The study did not include tones above 7,000 ~; therefore investigations ought to carry the work farther in the direction indicated. There is also a deplorable lack of discussion concerning the bearing of these experimental results on work that has already been accumulated, especially since they controvert much of it. Even when the factors are found to antagonize one another, instead of coöperating, the reader is left to his own devices.

Summary

The above critical review depicts what might seem like a modernistic painting or piece of sculpture. There are opposing lines and masses whose significance is hard to grasp by way of synthesis. One thing is positive: the volume of productivity and accompanying interest in auditory phenomena has grown by leaps and bounds. This statement would appear more impressive if the reader could see the pile of offprints, reference articles, and even books which the reviewer has had to leave unreported. But out of the welter of confusing details, opposite conclusions, and contradictory theories there remains a solid and crystallized mass of coherent meaning. May the reviewer, then, be pardoned for expressing what has come out of his experience in envisaging the literature year after year, in trying to keep abreast of it by way of information, in attempting to organize it systematically, and in writing this review? These are the salient ideas:

(1) Investigators are becoming increasingly aware of the complicated mechanism of the ear, both structurally and functionally. In a highly damped system, the hydrodynamic principles known under simpler conditions are not directly applicable. The possibility of further complication is present in view of the reflex operations of the tensor tympani and stapedius muscles.

(2) The newly discovered electric potentials of the various portions of the cochlea and of the eighth (auditory) nerve offer serviceable modes of attack. They should bear further investigation and results obtained by means of them must be carefully checked against psychological, physiological, and physical concepts which should be painstakingly distinguished.

(3) An increasing number of pathological materials are becoming available. In case of wasting or progressive diseases, however, unusual care must be exercised in the interpretation of post mortem findings. Important structural changes may have taken place since the final audiogram was recorded.

(4) A large amount of data concerning hearing in the lower animal realm is now becoming available. Techniques have been steadily improved, but, again, results obtained by electrical techniques should be carefully weighed against those secured by other methods of the CR type where voluntary responses can be more closely affiliated with the customary reactions of human subjects. In this area it is becoming increasingly clear that we move from noise discrimination and capacities to those of tone as we approach acuity and discrimination in the primates.

(5) The problem of sound localization, which is intimately tied up with auditory theory, is still in a somewhat confused state. The interplay of the component factors in a pattern response needs to be more carefully followed up. The importance of intensity differences is again emerging as a deciding factor especially with tones below 8,000 ~.

(6) Some modified form of resonance theory after the Helmholtz type, variously called a 'phase,' 'space-pattern' or 'zone' theory, appears to be the most applicable to the data at hand, except that for the higher ranges above 8,000 ~ some form of 'volley' theory, involving a serial or multiple response of the basilar fibers in stepwise distribution but within the wave-period of the incident disturbance, is in order.

In a general way these studies have emphasized what might be called the cosmopolitan character of research in the field of audition. The reviewer could not respect the boundaries of the various sciences: in fact today the boundaries can hardly be recognized. Physicists, physiologists, clinicians, otologists, as well as psychologists are all interested in the facts of hearing and resultant auditory theories. The promotion of an Institute of Acoustic Research, which would furnish a means of coördinating research in this field and of

providing for conferences of the symposium type, should be the aim of all serious investigators of auditory phenomena.

BIBLIOGRAPHY

1. ADRIAN, E. D., The Microphonic Action of the Cochlea: Wever and Bray's Experiments. *J. Physiol.*, 1931, **71**, xxviii–xxx.
2. BARTLETT, M. R., The Sensory Acuity of Psychopathic Individuals: A Comparison of the Auditory Acuity of Psychoneurotic and Dementia Praecox Cases with That of Normal Individuals. *Psychiat. Quart.*, 1935, **9**, 422–425.
3. BÉKÉSY, G. v., Zur Theorie des Hörens. *Physik. Zeits.*, 1929, **30**, 115–125.
4. CROWE, S. J., and HUGHSON, W., Eine neue Methode zur Untersuchung der Physiologie und Pathologie des Ohres. *Zsch. f. Hals.- Nas.- u. Ohrenhk.*, 1931, **30**, 65–76.
5. CROWE, S. J., HUGHSON, W., and WITTING, E. G., Function of the Tensor Tympani Muscle: An Experimental Study. *Arch. Otolaryngol.*, 1931, **14**, 575–580.
6. CULLER, E. A., An Experimental Study of Tonal Localization in the Cochlea of the Guinea Pig. *Ann. Otol., Rhinol., & Laryngol.*, 1935, **44**, 807–813.
7. CULLER, E. A., FINCH, G., and GIRDEN, E., Function of the Round Window in Hearing. *Amer. J. Physiol.*, 1935, **111**, 416–425; also *Science*, 1933, **78**, 269–270.
8. CULLER, E. A., FINCH, G., GIRDEN, E., and BROGDEN, W., Measurements of Acuity by the Conditioned-Response Technique. *J. Gener. Psychol.*, 1935, **12**, 223–227.
9. DAVIS, H., DERBYSHIRE, A. J., KEMP, E. H., LURIE, M. H., and UPTON, M., Experimental Stimulation Deafness. *Science*, 1935, **81**, 101–102.
10. DAVIS, H., DERBYSHIRE, A. J., KEMP, E. H., LURIE, M. H., and UPTON, M., Functional and Histological Changes in the Cochlea of the Guinea-Pig Resulting from Prolonged Stimulation. *J. Gener. Psychol.*, 1935, **12**, 251–278.
11. DAVIS, H., DERBYSHIRE, A. J., and LURIE, M. H., A Modification of Auditory Theory. *Trans. Amer. Otol. Soc.*, 1934, **24**, 110–119.
12. DAVIS, H., and SAUL, L. J., Action Currents in the Auditory Tracts of the Midbrain of the Cat. *Science*, 1931, **74**, 205–206.
13. DAVIS, H., and SAUL, L. J., The Frequency of Impulses in the Auditory Pathways. *Amer. J. Physiol.*, 1931, **101**, 28–29.
14. ELDER, J. H., Auditory Acuity of the Chimpanzee. *J. Comp. Psychol.*, 1934, **17**, 157–183.
15. FLETCHER, H., A Space-Time Pattern Theory of Hearing. *J. Acoust. Soc. Amer.*, 1930, **1**, 311–343.
16. GIRDEN, E., Effect of Roentgen Rays upon Hearing in Dogs. *J. Comp. Psychol.*, 1935, **20**, 263–290.
17. HENRY, F., The Meaning of 'Masking.' *Science*, 1936, **83**, 231–232.
18. HOLT-HANSEN, K., Studien über Schallokalisation. *Zsch. f. Psychol.*, 1931, **120**, 209–216.

19. HORTON, G. P., The Effect of Intense and Prolonged Acoustical Stimulation on the Auditory Sensitivity of Guinea Pigs. *J. Comp. Psychol.*, 1934, **18**, 405–417.
20. HORTON, G. P., An Experimental Study of Stimulation Deafness in Guinea Pigs. *Ann. Otol., Rhinol. & Laryngol.*, 1935, **44**, 252–259.
21. HUGHSON, W., and CROWE, S. J., Function of the Round Window, an Experimental Study. *J. Amer. Med. Assoc.*, 1931, **96**, 2027–2028.
22. HUGHSON, W., and CROWE, S. J., Immobilization of the Round Window Membrane: A Further Experimental Study. *Ann. Otol., Rhinol. & Laryngol.*, 1932, **41**, 332–348.
23. JELLINEK, A., Versuche über das Gehör der Vögel. I. Dressurversuche an Tauben mit akustischen Reizen. II. Gehörprüfungen an Tauben nach Exstirpation des Mittelohres. *Pflüg. Arch. f. d. ges. Physiol.*, 1926, **211**, 64–72, 73–81.
24. LURIE, M. H., DAVIS, H., and DERBYSHIRE, A. J., The Electrical Activity of the Cochlea in Certain Pathological Conditions. *Trans. Amer. Otol. Soc.*, 1934, **24**, 100–109.
25. MAIER, N. R. F., and SCHNEIRLA, T. C., *Principles of Animal Psychology.* New York: McGraw-Hill Book Company, Inc., 1935. Pp. xiii+529.
26. MUENZINGER, K. F., and GENTRY, E., Tone Discrimination in White Rats. *J. Comp. Psychol.*, 1931, **12**, 195–205.
27. PEARCE, S. H., The Pitch Specificity of Auditory Adaptation. *J. Gener. Psychol.*, 1935, **12**, 358–371.
28. RUCKMICK, C. A., An Institute for Acoustic Research. *Science*, 1922, **56**, 357–359.
29. RUCKMICK, C. A., Recent Acoustic Research. *Psychol. Bull.*, 1924, **21**, 605–633.
30. RUCKMICK, C. A., Auditory Sensations and Related Phenomena. *Psychol. Bull.*, 1927, **24**, 81–99.
31. RUCKMICK, C. A., Facts and Theories of Audition. *Psychol. Bull.*, 1928, **25**, 229–244.
32. RUCKMICK, C. A., Recent Research in the Field of Audition. *Psychol. Bull.*, 1930, **27**, 271–297.
33. TRIMBLE, O. C., Intensity-Difference and Phase-Difference as Conditions of Stimulation in Binaural Sound-Localization. *Amer. J. Psychol.*, 1935, **47**, 264–274.
34. WASHBURN, M. F., *The Animal Mind.* (Third Ed.) New York: The Macmillan Co., 1926. Pp. xiii+431.
35. WENDT, G. R., Auditory Acuity of Monkeys. *Comp. Psychol. Monog.*, 1934, **10**, No. 4, 1–51.
36. WEVER, E. G., The Upper Limit of Hearing in the Cat. *J. Comp. Psychol.*, 1930, **10**, 221–233.
37. WEVER, E. G., A Study of Hearing in the Sulfurwinged Grasshopper (Arphia Sulphurea). *J. Comp. Psychol.*, 1935, **20**, 17–20.
38. WEVER, E. G., The Physiology of Hearing: The Nature of Response in the Cochlea. *Physiol. Revs.*, 1933, **13**, 400–425.

39. WEVER, E. G., and BRAY, C. W., Action Currents in the Auditory Nerve in Response to Acoustical Stimulation. *Proc. Nat. Acad. Sci.*, 1930, **16**, 344–350.
40. WEVER, E. G., and BRAY, C. W., The Nature of Acoustic Response: The Relation Between Sound Frequency and Frequency of Impulses in the Auditory Nerve. *J. Exper. Psychol.*, 1930, **13**, 373–387.
41. WEVER, E. G., and BRAY, C. W., Auditory Nerve Responses in the Reptile. *Acta Oto-Laryngol.*, 1931, **16**, 154–159.
42. WEVER, E. G., and BRAY, C. W., A New Method for the Study of Hearing in Insects. *J. Cell. & Comp. Physiol.*, 1933, **4**, 79–93.
43. *Report of a Discussion on Audition Before The Physical Society.* London: The Physical Society, 1931. Pp. 157.
44. Symposium Before the American Otological Society. Toronto, May 27, 1935. *Ann. Otol., Rhinol. & Laryngol.*, 1935, **44**, 736–837.

FUNCTIONAL RELATIONSHIPS IN TACTUAL AND PROPRIOCEPTIVE SYSTEMS

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Introduction. The purpose of this paper is briefly to review certain studies which represent various phases of activity in the field of touch and proprioception, and to evaluate critically some of the generalizations which have been formulated on the basis of experimental data that are now available. Although it is not feasible here even to enumerate the approximately two hundred studies which have appeared in this field since last a review of this general topic was published in the BULLETIN (41); nevertheless, the reader will not fail to recognize that, in respect of certain of the wider generalizations which are made in the paper, the 'silent' studies play an influential supporting rôle.

Gradually the investigations in this field are coming to subscribe to a more strict scientific standard. Functional relationships for a number of different aspects of these sensory processes are being expressed in terms of specific quantitative variables. Experiments concerning adaptation-time show the manner in which the duration of a given process is functionally dependent upon the variable of amount of stimulus; experiments upon acuity reveal that discriminative judgments of sameness and difference of locality, and of unitariness and duality of impression, depend upon critical distances of separation between 2 successive or simultaneous punctate stimulations on the skin; and experiments which relate to intensity, or preferably sensitivity, indicate the manner in which judgment of the least perceptible difference that can be discriminated with certainty varies as a function of increase in amount of stimulus. These are typical instances in which measurement of the sensory processes under consideration has been carried out in a definitely quantitative way.

Qualitative and Functional Approaches. Such processes as result from stimulation on the elastic skin are studied from two essentially distinctive viewpoints: (1) the qualitative and (2) the functional. The former is chiefly concerned with the problem of denoting the

primary qualities which might serve as the cornerstones for a qualitative manifold; and with specifying the typical stimuli, and the receptors "underlying" these qualities. This approach also has regard for the qualitative resultants which follow upon simultaneous excitation of two or more primary qualities. The functional approach, however, has an essentially different emphasis. The object here is to reveal the manner in which various kinds of sensory relationships may be differentiated from a complex system of organic tissue which is characterized by such functional properties as sensitivity, conductivity, responsiveness, and the like; and in particular, to set forth in terms of quantitative dimensions the functional relationships that may exist between an aspect of the process, which is the effect of activation in the given system, and a measurable variant of the stimulus.

The functional approach is tending to outmode the qualitative approach. The former attack offers greater advantages for the comparative study of sensory relationships in different animal forms. It includes with greater certainty such significant investigations as are being made with the aid of electrical recording devices—galvanometers, capillary electrometers, oscillographs and the like. During the past five or ten years, workers who adhere more to the functional approach have been more productive, not only in point of number of contributions, but also with respect to treatment and generally representative interpretation of obtained data. It is perhaps pertinent to note that workers are tending to shift from the qualitative to the functional mode of envisagement of problems in the context under discussion.

Adaptation Time. Measurement of adaptation time to pressure, as reported by Zigler from experiments in the Clark and Wellesley laboratories, reveals a functional relationship between amount of stimulus per unit area and duration of sensory process (**39**). In his own laboratory, cylindrical weights which varied from .05 to 2 gm. and which were between 5 and 25 mm. diameter were used in 4 different regions of the skin (cutaneous pressure); in the other experiment, all of the weights used had the same area, but varied in amount between 8 and 88 gm. Measurement of the duration of the pressure process during continued presentation of these stimuli revealed that the functional relationship in question was measurable with reasonable consistency. The results were interpreted as suggesting a linear relationship between adaptation time and the amount of the stimulus per unit area.

Recently, the foregoing data were plotted by Crook and Crook, who also performed adaptation experiments with a range of weights extending to an upper limit of 250 gm. (9). (The title of their paper—*Adaptation to Cutaneous Pressure*—is therefore misleading.) They found that their results, as well as the plotted results of the earlier study, manifested a similar tendency to deviate from the suggested linear relationship. Since the processes for heavier stimuli, particularly for 1 of the 2 subjects, required some increment of time which eventually tended to decrease at the upper limit, they point out that the functional relationship is slightly sigmoid, and is not subject to any "simple" analysis.

Burns and Dallenbach failed to find a consistently measurable relationship between duration of process and amount of stimulus during continued presentation of a number 10 sewing needle (6). This finding probably will not come as a surprise to the sophisticated experimental psychologist. It is commonly recognized that pain presents exceptions to the laws which apply to pressure; and after all, a definite functional relationship is less likely to be found with stimulus intensities of small compass than with a more extended range.

The relationship between adaptation time and amount (or kind) of stimulation on the skin of the frog has been carefully studied from oscillographic records that were taken from cutaneous nerves which supply the field of stimulation (1, p. 35 f.; 8; 21; 24). It is a significant fact that this method reveals relatively brief adaptation times (rapid failure) during stimulations with successive puffs of air and with 20% acetic acid. Allowing for individual differences in the various subjects and for differences in amount and kind of stimulation (weights, puffs of air, acetic acid), adaptation time as indicated by the oscillographic technique seems to be much briefer than as indicated by verbal report of the human subject.

Tactual Acuity. Acuity denotes the limit of functional efficiency for discrimination of details in the extensive variable of the stimulus. Most commonly determinations of tactual acuity take the form of trials concerning the average error of localization or the two-point limen. There are, of course, other measures of tactual acuity, but these 2 classical experiments have been so fruitful and are so well known that they are taken as typical for determinations of tactual acuity.

The controversy between Von Skramlik and Ponzo in regard to the relative magnitude of the average error of localization for stimulations of pressure and of pain was the basis of the study by Zigler, Moore, and Wilson (42). These workers used a thistle as stimulus

for pain, and a horse-hair of 1 gm./mm. tension for pressure stimulation. The average error of localization for thistle stimulations was found to be slightly smaller than was the corresponding value for stimulations by the horse-hair. In order the more nearly to equate conditions, another experiment was performed in which stimulations by the thistle were classified by the subject according to the quality that was aroused: (1) pain, (2) pressure, and (3) pressure-pain complex; and the average error of localization for the 3 classes separately determined. The result was that pressure-pain complexes were most, and pressure stimulations were least accurately localized, although differences here were relatively small. The slightly greater accuracy in the localization of pressure-pain complexes was attributed to the probably less homogeneous type of excitation in the sensory system. Disher confirmed the contention of Ponzo, namely, that the magnitude of the average error of localization is not functionally dependent upon the amount of the stimulus (**12**). Sixty determinations for each of 6 different amounts between 12 and 300 gm. were made in 2 different regions in 5 subjects.

Hoagland and Berkovich made successive applications of discs of filter paper that were saturated with 15% acetic acid to the skin of the frog, a concentration known to be sufficient to destroy the sensory endings after some minutes of application (**25**). Oscillographic records taken from the nerve which supplied the experimental field revealed rapid failure of type A impulses and consequent increase in reaction time. Only crude localization was evinced during conduction of impulses of the B and C types.

Madlung investigated the *Anziehungseffekte* which Von Frey described in connection with localization experiments, namely, that the stronger of 2 stimulations tends to absorb the weaker, and that the longer of 2 distances marked off by 3 punctate stimulations on a line appears to be shorter when a heavier stimulation is made at the outer limit of the longer of the 2 intervals (**28**). Control series included trials in which equal stimulation was made at the 3 points of application. The study revealed that the attraction effect is not restricted to the cutaneous field of a single member such as the arm, but occurs just about as definitely when one stimulation is made on one arm and the second on the other arm, the arms being placed in the frontal-parallel position, the one outside the other. The effect does not require anatomical continuity, nor does it follow the course of anatomical structures; it takes place, as it were, 'through the air.' The strength of the phenomenon depends upon the amount of the

difference between the intensities at the 2 stimulations, and upon the proximity of the arms. At a separation of 90 cm. between midpoints of the 2 arms, the phenomenon reaches a minimum.

Heretofore the average error of localization and the two-point limen, for the most part, have been treated as separate experiments. However, the desirability of a basis of comparison between the 2 values for a given region of the skin has been indicated. Zigler has shown that both determinations may be made under conditions that permit direct comparison between the 2 values (**40**). With secondary differences between the conditions in the 2 experiments reduced to a minimum, psychophysical determinations were made under passive conditions in both experiments. Under these conditions, the magnitude of the average error of localization was found to be about one-fourth that of the simultaneous two-point limen, and a little less than one-third that for the successive two-point limen for a region near the midpoint on the volar forearm. The value for the simultaneous two-point limen was about one and one-half times that for the successive two-point limen. Suggestions were made regarding psychophysiological differences in the 2 experiments. Judgments of unitariness or duality of impression for successive or simultaneous application are generally believed to depend upon separateness at the outer limit of the adjacent sides of the 2 excitations (dispersion circles). The excitations for the two-point limen can be discriminated more accurately in successive than in simultaneous applications because in this case the earlier undergoes change before the second occurs. But since the error of localization is much smaller than is either the simultaneous or successive two-point limen, it must depend upon 2 overlapping 'local excitatory processes.' Here it was suggested that discriminations between sameness and difference of the 2 succeeding stimulations depend upon the degree of spatial distinctness that exists between the 2 maxima at the center of the 2 overlapping excitatory processes. These maxima denote the points at which the action of the stimulus in each of the 2 applications was greatest. This specification as regards the psychophysiological basis of the 2 experiments gives clarity to the relation of these conventional experiments.

Hoagland attempted to specify the nature of the basis of the problem of localization in the frog (**22**). He indicated that the study by Adrian, Cattell, and Hoagland revealed that sensitive areas for individual dorsal cutaneous nerves are not discrete in the skin of the frog but overlap a great deal. He suggested that different patterns of impulse frequencies in a number of fibers

may constitute the peripheral 'local sign' in terms of which localization on the skin is determined.

Intensity. Functional relationships in the realm of the intensity of sensory processes are commonly measured in terms of the ratio between the increment of the stimulus which can just be discriminated and the absolute value of the stimulus. The manner in which this ratio, commonly designated $\Delta R/R$ (or $\Delta I/I$), varies as a function of increase of R (or I) in touch has been the subject of much study, but interpretation of the results has remained uncertain because of such variable conditions as stretching of tissues, the complication of subcutaneous stimulation, and the influence of surrounding receptor units.

Recently Gatti and Dodge resorted to the expedient of destroying surrounding touch spots with a glowing needle, and then tested the remaining touch spot for sensitivity to change in amount of pressure (13). They stimulated with the end of a horse-hair (.125 mm. diameter and 1.5 mm. long) at 8 points on the continuum of stimulus-intensity (.1 to .8 gm.=.8 to 6.4 gm./mm.), a range which extended from just above the threshold to an intensity that produced pain. Stimulations were made by means of the Dodge touch-balance which controlled the duration of stimulation to .16 second with an accuracy of .1 second, and the interval between stimulations to 1.6 seconds.

The study by Dodge and Gatti shows that $\Delta R/R$ varies with R: the Weber fraction decreases, at first rapidly and then slowly, and finally tends to increase. That their results fail to show a constancy of $\Delta R/R$ as a function of R is attributed to inattention, which they suggest must have played some rôle in the 8,000 determinations. The results are thus not in keeping with the requirements of Weber's law. They consider a corrective factor which transmutes the values more nearly to a constancy, a device which Helmholtz adopted in vision for the same purpose long ago and which was called into question by Aubert and Hering. Nevertheless, the data of Gatti and Dodge show definitely the manner in which $\Delta R/R$ depends upon amount of stimulus in pressure. This is a prudent conclusion, particularly in view of the fact that their work shows unusual care in control of conditions during stimulations, and that the data harmonize with the results obtained concerning the behavior of $\Delta R/R$ as a function of R in other sensory systems.

Another approach to this problem is revealed in a later study by Gatti and Dodge (14), and in the recent work of Bernfeld and Feitelberg (7). Instead of studying the conventional psychophysical relationship, these workers were concerned with the manner in which

depth of deformation depends upon increase in weight, and with the possibility that measurement of this relationship may be more meaningful than is 'psychophysical' measurement.

Gatti and Dodge took photographic records of the course of deformation as a function of increase in pressure for 2 regions of skin (14). On the tip of the finger, pressures between the limits of .2 and 10 gm., and on the volar forearm, pressures between the limits of .2 and 1 gm. were used. Applications were made with the Dodge touch-balance. Although these workers regard their study as preliminary, they assert that it indicates that the units of physical pressure give no true picture of the adequate stimulus. The curves for the 2 regions are not alike; but, in view of the fact that a much earlier study by Gatti revealed that psychophysical measurements in these 2 regions yield different results, the present finding that a constant relationship exists between amount of weight and depth of deformation for the volar forearm but not for the finger-tip was accepted as signifying that sensory functions in the 2 regions of the skin are unlike. On the finger-tip, depth of deformation was proportional to the cube root of the stimulus squared.

Bernfeld and Feitelberg made a more extended study of the depth of deformation in stimulation on the skin (7). They point out that the relation between weight and depth of deformation cannot be linear since the bones introduce conditions which denote a maximum. Weights were applied in this investigation by a balance system which included an indicator for depth of deformation. Cylindrical (2 to 10 mm. diameter), spherical (1 to 4 mm. diameter), conical, and needle points were applied on the finger, hand, and lower arm. Great variation in depth of deformation was found between individuals, and from region to region in the same subject. However, if the results for the conical stimuli and those which resulted in pain are excluded, 93% of the readings for the relationship between depth of penetration and weight satisfy the equation $y=\frac{cx}{a+x}$. Experimental results of Gatti and Dodge and others are shown also to satisfy this equation.

Experiments also were carried out by the 'method of minimal changes with equidistant stimuli' (.25 and .5 gm.) to determine the relationship between depth of deformation and the differential threshold. The results obtained, on initial inspection, reveal a different function from that which is obtained when the relationship

between weight and the threshold is determined. But these workers think that these different functions are nevertheless parameters of the same family of curves. Considerations regarding the meaning of the constants in the obtained equations lead to the concept of 'work done' (*Reizarbeit*), the principal component of which is force.

Somesthesis. Dallenbach has recently subsumed under the caption of somesthesis all the 'congeries of unrelated sensory qualities' which derive from sense organs in the skin, muscles, tendons, ligaments, bones, joints and other internal organs (11, p. 154). Boring used a similar term—somesthesia—in essentially the same, although apparently in a somewhat more restricted sense a little earlier (4, p. 171). That a general term is here required denotes a growing recognition that the receptors which are embedded at various depths in the elastic tissues of the body evince a functional continuity of response to changes in tension that are imposed by muscular contraction and by other changes in the associated tissues. The term "proprioception," however, seems more specifically to represent the material presented in this review.

Proprioception. Measurement of functional relationships in the proprioceptive system have been made both in human and in animal subjects. As an example of the most exact measurements that have been made in this system, we may perhaps best cite the work of Crozier and Pincus, in which a very definite functional relationship relative to the geotropic orientation of young rats during progression over an inclined plane is exhibited (10). These workers found that the angle of bodily adjustment (θ) which the animal makes, presumably so as to effect 'sensorially equivalent bilateral excitation' in the proprioceptive system, is a definite and reproducible function of angle α. Θ is approximately proportional to the logarithm of the magnitude of the effective force, the gravitational component of the surface of inclination. The function for this dependency over the entire working range is described as an elongated, sigmoid curve. The curve was differentiated to determine the rate of change at which increase in steepness made increasing demands upon the tensive receptor groups, and was analyzed as signifying 3 subgroups of functional receptors. The θ–α curves for individuals of a given race of rats of pure stock are all of the same general form. More recently these workers have been concerned with the manner in which a small load, attached at different points along the back of the animal, produces variation in the behavior of the curve. This new and very

promising approach to the study of proprioception has been utilized for more detailed specification as regards the location and extent of the additional receptors which are thus called into activity.

Functional relationships in the proprioceptive system in the human have been less completely and less definitely determined, although study of proprioception in the human has manifested a sharp upswing. These studies, in general, are concerned with the efficiency of proprioceptive adjustment when sight is excluded.

We single out for brief mention several of the studies that are typical. Gurnee found that sensitivity to downward movement on a teeter-board set up was greater than was that to upward movement; that right responses and invariance were both directly related to velocity of movement; and that judgment depended upon cutaneous and kinesthetic pressures, with the former predominating at the fastest rate used (**16**). Von Skramlik found that after a standard distance had been given with the arm being moved at 60 cm./sec., the comparison distance that was estimated to be equal to it when rate of movement was between 1 and 5 cm./sec. was too short; the magnitude of this error was inversely related to speed (**33**). Klingelhage determined that reproduction of a touched point in one of the coördinates of space was less erroneous when made by the same hand than when made by the other hand, or by the same hand with rotation at the wrist (**26**). Stock found that reproduction of the symmetrical point on the other side with respect to the median plane was more inaccurate when the arms were crossed than when they were parallel (**34**). Liebig reported that a small point of light was indicated more accurately after the subject had been led than after he had been conveyed in a cart a given distance following the orientation, and that the amount of the error was a direct function of complexity and extent of change in position (**27**). Gräf reported upon the nature of errors that were made in attempting to reproduce distances on the opposite side with respect to the median plane (**15**). Breternitz found that Tortual's illusion (1827) does not depend entirely upon the magnitude of the angle of adjustment, but partly upon mental estimation of length, which varies with remoteness (**5**). Both Heym and Pauling determined the fact that a more remote extent must be objectively greater than a nearer one in order to appear equal to it (**20, 31**).

These studies call attention to interesting facts regarding proprioceptive error when sight is excluded, and reveal some of the points at which, under given conditions, error is least or greatest. They also have the merit of measuring in terms of the 3 dimensions of space. The total effect of these studies is to shift the focus to proprioceptive variability and thus toward another functional relation in the proprioceptive system. With the marked interest that now is being manifested in the problem of proprioception, it is doubtless only

a matter of time until more exact functional relationships in the proprioceptive system of the human subject also will be definitely and completely determined.

Quality. Although relationships have been suggested as existing between certain aspects of somesthetic processes and a given variable in the stimulus, not all aspects have as yet been successfully related to a quantitative variable. Quality is, of course, a point of orientation in touch and proprioception just as it also is in other fields of sense. We are concerned not merely with qualitative characterization, but also with the deeper problem of differentiation of the receptors that are required as a physiological basis for the qualitative nuances. It is because of this aspect of the problem that the qualitative was designated one of the approaches which converge upon problems of touch and proprioception (*vide supra*). This approach was in the ascendancy for many years and still commands a distinguished following. The notable contributions of the late Max von Frey may be cited as typical (cf. **3, 30**).

Explanation for differentiation of qualities in tactual and proprioceptive systems is a pressing problem, and painstaking efforts have been made in the attempt to solve it. Boring (1933) summarily stated that "apparently not less than two, nor more than four, kinds of receptors are needed by current theory"(**4**, p. 185). Dallenbach (1935) designated 2 kinds of receptors for pressure, 1 kind for pain, and pointed out that "the end-organs for cold and warmth are still unknown despite repeated efforts to identify them"(**11**, p. 170).

The problem of differentiation of receptors is paralleled by the problem of specification regarding the stimulus. The same stimulus, *e.g.* a thistle, presented a number of times does not invariably produce the same quality. We can merely designate typical stimuli, but not strictly specific stimuli for the several qualities in touch.

The qualitative is opposed by a 'quantitative' theory; the basis for the challenge of the latter is insufficient evidence. It alleges that anatomical distinctions relative to nerve terminals in the tissues are "without importance for psychology"(**29**, p. 1077). The quantitative theory posits that quality must be explained in terms of variables capable of quantitative expression, *e.g.* space and time, as regards the pattern of excitation in systems of sensory nerves. It is apparent that this theory is merely a special form of the functional approach which attempts to come to grips with the problem of quality incidentally *via* functional relationships which are revealed during

variation in measurable modes of stimulation. Credit for effectively orienting the problem of quality in touch to the functional approach must go to Nafe, who first propounded this quantitative theory.

Qualitative changes that occur in sensory systems in the skin and associated tissues during continued presentation of a stimulus have been made recently both in frog and human subjects. Adrian made the observation that a series of qualities follows compression of the skin: " we feel first touch, then pressure, and finally pain "(1, p. 43). Burns and Dallenbach applied a number 10 sewing needle steadily to the skin of the forearm until complete adaptation was established (6). After an interval of 1.5 to 2.2 seconds following presentation, pain was reported. This quality then subsided gradually through a series of phases which finally included mere pressure. The phases denote various degrees of pain and pressure; they were: (1) intense sharp pain, (2) sharp pain, (3) pain, (4) dull pain, (5) weak pain, (6) pressure, (7) weak pressure, (8) tickle, and (9) nothing. Since the sewing needle was an adequate stimulus both for pressure and for pain, the writers reserved judgment as regards the functional receptors signified. The work was continued in a study by Stone and Dallenbach, who aimed to overcome the possible complication of pressure stimulation during adaptation to a stimulus for pain. In the hope of achieving this end, a ' radiant heat ' stimulus having a small spot of 2 mm. diameter was used (35). But it is very doubtful, as these men indeed seem to recognize, if the selection of this stimulus accomplishes more than the reduction of the pressure component to a minimum. Such a stimulus probably induces local expansion in the tissues. The principal qualitative phases which were reported in this study were warmth, pain, and again warmth. The authors were especially interested in the relationship between pain and pressure which was left unsettled in the study by Burns and Dallenbach. Since pressure was only rarely reported in these stimulations, Stone and Dallenbach drew the conclusion that pain is not the result of summation of pressure as was posited long ago by Goldscheider. In another study, Stone and Dallenbach were concerned with qualitative changes which occurred during continued presentation of a larger stimulus: a field of 7 needles, 6 placed at the points of a hexagon of 15 mm. diameter and the seventh at the midpoint (36). The results of this study also were interpreted as signifying different receptors for pressure and pain.

Adrian recorded action potentials in cutaneous nerves of the frog during continued stimulation on the skin and found reason to distinguish between (1) receptors which manifest 'rapid failure' and (2) those which evince slow adaptation (1). The hair endings in the skin typify the former, and the muscle spindles the latter. However, Adrian was not disposed to interpret these findings as signifying a fundamental difference between the mechanism of the hair ending and that of the muscle spindle, since "some muscle spindles adapt fairly rapidly and some hair endings fairly slowly" (1, p. 25).

Separate receptor systems are assumed for pressure and pain by others who have studied functional relations in the sensory system of the skin with a similar technique. Cattell and Hoagland stimulated the skin of the frog by means of an interrupted air jet of high frequency for relatively long periods of time (8). Although it is known that the receptors which are here being stimulated manifest rapid failure during steady stimulation, they fail to reveal anything like summation during prolonged high frequency stimulation with the interrupted air jet. Frogs pay no more attention to these stimulations than they do to touch. Thus, in this study also, the view of Goldscheider regarding the relationship of pain and pressure is not confirmed, and the assumption that there are separate receptors for pressure and pain is not contradicted.

Bazett and McGlone tested the theory of Ebbecke, which states that thermal sensation is the result of the establishment of a thermal gradient in the tissues (2). After approximating thermal equilibrium by leaving the arm immersed in a bath for 20 or 30 minutes, stasis was induced in the arm or finger; temperature control was effected in terms of thermocouples placed on the skin and at various depths in its layers. Upon release of stasis that had been maintained for 5 to 15 minutes and during which temperature varied less than .05° C., intense warmth and heat were induced. The sensory effects were more intense both for longer as compared with shorter periods of stasis, and for stasis of the arm as compared with that of the finger. The need for modification of the thermal gradient view is indicated, and a chemical gradient view of stimulation is suggested. The possibility that this may be due to metabolic products, which accumulate in the blood during stasis, *e.g.* acidity, is not very favorably entertained, owing to the fact that the tissues here are sensitive to warmth when temperature changes are so small that only a negligible change in carbon dioxide would be produced, whereas high percentages of carbon dioxide (10%) are required to produce warmth by inhalation; and moreover, injection of other chemical substances such as magnesium and calcium chloride has the same effect.

Nafe made correlations between (1) changes in the appearance of plain muscle as induced by variation of temperature and (2) quality (29, p. 1054 f.). As temperature was increased, more and more muscle elements underwent dilatation, and warmth was perceived. Constriction began at about 54° C., and heat was the result. Pain dominated the experiences when spastic contraction was observed; it began with a temperature of about 50° C. Reduction of temperature to about 10° below the temperature of the blood resulted in light constriction, which increased as temperature was reduced still farther; here the experience resembled heat. At extremely low temperatures, spastic contraction occurred and pain was the dominating quality. The descriptions indicate that such stimulations do not give rise to homogeneous patterns in these tissues, particularly at the two extremes of stimulation.

Wilde concludes that pain depends upon a central process that is somehow founded upon a peripheral basis of sensory processes (38). His method was gradually to increase the temperature of a stimulus until it became unbearable. The 19 subjects were differentiated into 3 principal types, with 2 intermediates. The first evinced a change from warmth to areal burning; the second, transitions from warmth to pricking sensation to continuous pain; the third, a series which included in ascending order: (1) warmth, (2) contact, (3) prick, and (4) burning. It may be noted that these three primary types are not entirely distinctive. The study revealed also that pains from minimal temperatures that were effective for this quality were sometimes designated not unpleasant, and that length of interval between changes in quality depended upon the velocity of the change of temperature in the stimulus.

Heiser reported that frequency of warmth to stimulation on the skin is a function of stimulus-temperature (17). Heiser and McNair found that between the limits of 1 and 6 gm., thermally indifferent stimulation was effective for warmth, and that the frequency of these reports was a function of amount of stimulus-pressure (19). A later study yields no functional relationship between duration of a stimulus of constant temperature (39° C.) within the limits of .5 and 4 seconds and the process of warmth (18).

Matthews has reported that the action potentials which are taken from cutaneous nerve in a frog during stimulation with heat are intermediate between those known to typify tactile and injury stimulation both in respect of magnitude and conduction velocity (cf. 1, p. 58).

Hoagland tested antidromic areas in the skin of the frog, areas which are supplied by single nerve fibers (24). Tests were made with 20% acetic acid and by brushing lightly with the tip of a feather. The oscillographic records revealed, in general, that individual areas respond to only one of the kinds of

stimulation; although, in 10 instances, stimulation by both acetic acid and by the feather was effective in the same antidromic area.

Waterson found that the epidermis can be cut away through its deep layer (*stratum mucosam*) without arousing pain, and was thus prompted to propound the view that the receptors in the epidermis are tactile organs and not pain organs as is the conventional view (**37**). He also alleges that this, and other observations, indicate that some other function must be found for Meissner corpuscles and Pacini bodies. His view is supported by statements to the effect that sensations of touch are not elicited in areas that are denuded of the epidermis, and that the stimulus which is adequate for the sensation of touch is so small in the normal skin as to make it 'impossible' for the organs deeper in the corium to subserve touch. What this writer seems to fail to consider, however, is the possibility that the receptors are widely distributed.

Experiments in regions of translocated tissues bear upon the question of specificity in sensory nerves. Purdy has reported a case in which the first phalanx of the middle finger was removed and the volar skin drawn over the end of the joint and stitched to the skin of the dorsal parts (**32**). The area manifested hypersensitivity to warmth, but was less sensitive to cold than was the surrounding area. A definite gap was experienced in the sensory field when the finger was plunged into cool water. Stimulation on the line of suture, even by a horse-hair, resulted in double impression. The illusion that is typical in cases of amputation was also reported, and was said to persist even when the subject was permitted to witness the application of the stimulus.

BIBLIOGRAPHY

1. Adrian, E. D., *The Mechanism of Nervous Action: Electrical Studies of the Neurone.* Philadelphia: Univ. of Pennsylvania Press, 1932. Pp. x+103.
2. Bazett, H. C., and McGlone, B., Studies in Sensation. III. Chemical Factor in the Stimulation of End-Organ Giving Temperature Sensations. *Arch. Neurol. & Psychiat.*, 1932, **28**, 71–91.
3. Boring, E. G., Max von Frey: 1852–1932. *Amer. J. Psychol.*, 1932, **44**, 584–586.
4. Boring, E. G., *The Physical Dimensions of Consciousness.* New York: The Century Company, 1933. Pp. xii+251.
5. Breternitz, W., Ueber die Tourtualsche Täuschung. *Zsch. f. Sinnesphysiol.*, 1934, **65**, 146–165.
6. Burns, M., and Dallenbach, K. M., The Adaptation of Cutaneous Pain. *Amer. J. Psychol.*, 1933, **45**, 111–117.

7. BERNFELD, S., and FEITELBERG, S., Deformation, Unterschiedsschwelle und Reizarbeit bei Druckreizen. *Arch. f. d. ges. Psychol.*, 1932, **83**, 197–260.
8. CATTELL, J. McK., and HOAGLAND, H., Response of Tactile Receptors to Intermittent Stimulation. *J. Physiol.*, 1931, **72**, 292–404.
9. CROOK, M. N., and CROOK, H., Adaptation to Cutaneous Pressure. *Amer. J. Psychol.*, 1935, **47**, 301–308.
10. CROZIER, W. J., and PINCUS, G., Analysis of the Geotropic Orientation of Young Rats. *J. Gener. Physiol.*, 1932, **15**, 421–462; 1933, **16**, 801–813; 1933, **16**, 883–893.
11. DALLENBACH, K. M., Somesthesis. Pp. 154–187 in Boring, E. G., Langfeld, H. S., and Weld, H. P. (Eds.), *Psychology: A Factual Textbook*. New York: John Wiley and Sons, Inc., 1935.
12. DISHER, D. R., The Effect of Pressure Magnitude on Cutaneous Localization. *J. Gener. Psychol.*, 1933, **9**, 390–404.
13. GATTI, A., and DODGE, R., Über die Unterschiedsempfindlichkeit bei Reizung eines einzelnen, isolierten Tastorgans. *Arch. f. d. ges. Psychol.*, 1929, **69**, 405–426.
14. GATTI, A., and DODGE, R., Über die Deformation der Haut in einer Reihe von Druckwerten. *Arch. f. d. ges. Psychol.*, 1929, **71**, 481–492.
15. GRÄF, A., Über die haptisch symmetrische Einstellung von Strecken. *Zsch. f. Sinnesphysiol.*, 1934, **64**, 283–309.
16. GURNEE, H., Thresholds of Vertical Movement of the Body. *J. Exper. Psychol.*, 1934, **17**, 270–285.
17. HEISER, F., Stimulus Temperature and Thermal Sensation. *Arch. of Psychol.*, 1932, **21**, No. 138. Pp. 1–81.
18. HEISER, F., Stimulus-Duration and Cutaneous Sensations of Warmth. *Psychol. Bull.*, 1933, **30**, 691.
19. HEISER, F., and MCNAIR, W. K., Stimulus-Pressure and Thermal Sensation. *Amer. J. Psychol.*, 1934, **46**, 580–589.
20. HEYM, H., Ueber das beidhändige Tastmass. I. *Zsch. f. Sinnesphysiol.*, 1934, **65**, 166–188.
21. HOAGLAND, H., Adaptation of Cutaneous Tactile Receptors. II. *J. Gener. Physiol.*, 1934, **18**, 255–264.
22. HOAGLAND, H., A Basis for Cutaneous Localization. *J. Gener. Psychol.*, 1932, **6**, 468–470.
23. HOAGLAND, H., Quantitative Aspects of Cutaneous Sensory Adaptation. I. *J. Gener. Physiol.*, 1933, **16**, 911–923.
24. HOAGLAND, H., Specific Afferent Impulses and Cutaneous Sensibility. *J. Gener. Psychol.*, 1932, **6**, 276–295.
25. HOAGLAND, H., and BERKOVICH, L., On the Neurological Basis of the Localized Response to Irritants on the Skin. *J. Gener. Psychol.*, 1933, **9**, 365–376.
26. KLINGELHAGE, H., Mit welcher Sicherheit wird ein den Tastwerkzeugen dargebotener Raumpunkt haptisch wieder aufgezeigt? *Zsch. f. Sinnesphysiol.*, 1933, **64**, 192–228.
27. LIEBIG, F. G., Über unsere Orientierung im Raume bei Ausschluss der Augen. *Zsch. f. Sinnesphysiol.*, 1933, **64**, 251–282.

28. MADLUNG, K., Über anschauliche und funktionelle Nachbarschaft von Tasteindrücken. *Psychol. Forsch.*, 1934, **19**, 193–236.
29. NAFE, J. P., The Pressure, Pain and Temperature Senses. Pp. 1037–1087 in Murchison, C. (Ed.), *A Handbook of General Experimental Psychology*. Worcester: Clark Univ. Press, 1934.
30. PAULI, R., Die Erforschung der Haut- und Muskelempfindungen. (Max von Frey zum Gedächtnis.) *Arch. f. d. ges. Psychol.*, 1933, **88**, 231–252.
31. PAULING, K., Das Tastmass bei Gelenkbeanspruchung. *Zsch. f. Sinnesphysiol.*, 1934, **65**, 189–214.
32. PURDY, D. M., Tactual Space Perception in Translocated Tissue. *J. Gener. Psychol.*, 1934, **10**, 227–229.
33. SKRAMLIK, E. VON, Über die Beeinflussung unserer Tastwahrnehmungen durch Richtung und Schnelligkeit der Tastbewegung. *Zsch. f. Sinnesphysiol.*, 1933, **64**, 97–114.
34. STOCK, B., Über die symmetrische haptische Einstellung von Raumpunkten. *Zsch. f. Sinnesphysiol.*, 1933, **64**, 229–250.
35. STONE, L. J., and DALLENBACH, K. M., Adaptation to the Pain of Radiant Heat. *Amer. J. Psychol.*, 1934, **46**, 229–242.
36. STONE, L. J., and DALLENBACH, K. M., The Adaptation of Areal Pain. *Amer. J. Psychol.*, 1936, **48**, 117–125.
37. WATERSON, D., Observations on Sensation: The Sensory Functions of the Skin for Touch and Pain. *J. Physiol.*, 1933, **77**, 251–258.
38. WILDE, K., Zur Phänomenologie des Warmeschmerzes. *Psychol. Forsch.*, 1935, **20**, 262–321.
39. ZIGLER, M. J., Pressure Adaptation-Time: A Function of Intensity and Extensity. *Amer. J. Psychol.*, 1932, **44**, 709–720.
40. ZIGLER, M. J., The Experimental Relation of the Two-Point Limen to the Error of Localization. *J. Gener. Psychol.*, 1935, **13**, 316–332.
41. ZIGLER, M. J., Touch and Kinesthesis. *Psychol. Bull.*, 1932, **29**, 260–278.
42. ZIGLER, M. J., MOORE, E. M., and WILSON, M. T., Comparative Accuracy in the Localization of Cutaneous Pressure and Pain. *Amer. J. Psychol.*, 1934, **46**, 47–58.

DEFECTS OF COLOR VISION: THEIR VOCATIONAL INCIDENCE AND PRACTICAL CONTROL; ACQUIRED DEFECTS

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The present paper is the first of a series dealing with the literature on defects of color vision for the period from 1923 to 1935.* Histories and general discussions of the problem of color defects are available in a number of studies (**16, 20, 29, 33, 34, 40, 41, 70, 111,** and **115**). A note by Edridge-Green (**51**) takes the history of reported cases of color defectives back to the year 1688.

Vocational Incidence. Destounis (**43**) points out a case of hallucinatory and paranoid tendencies possibly aggravated by vocational consequences of protanopy. Various authors have cited the importance of normal color vision for at least 25 different vocational activities (**38, 66, 120, 157**). Yet among railroad employees Reim (**127**) found that 0.76% were defective, Kalashnikov (**79**) found about 10.0%, Blum and Schaaf (**20**) about 1.0%, and Verrey (**149**) about 6.8%. The writer of (**8**) reported that 2.9% of a group of German sailors were defective, and the writer of (**12**) reported defectives among a group of English seamen to the extent of 3.3%, and among a group of recruits to the extent of 1.7%. Miles and Craig (**104**) found that 4.0% of a group of dry-goods salesmen were defective. Among groups of medical students Macklin (**95**) found about 11.0%, and Tocantins (**146**) found 12.8% who were red-green blind. Gil and Adrogué (**62**) found that 4.0% of applicants for a police force were defective.

Control by Tests. In general, the testing of applicants and periodic retesting of employees constitute the chief means of control of color defects. These testing programs generally exhibit more respect for the quasi-scientific thoroughness of the tests used than for the actual demands of given vocations. Difficulties arise when attempts are made to satisfy both scientific and practical requirements (cf. Preston, **123**). Thus Engelking (**55**) creates unnecessary problems in an attempt to define color-fitness (*Farbentüchtigkeit*)

* For other reviews of this field see S. P. Hayes' article in this journal, 1926, **23**, 547–573, and his earlier articles.

and evaluates test procedures in relation simultaneously to the incompatible criteria of classical typologies and practical needs. Bourdier and Schaaf (**29**) distinguish between the demands of practical testing, those of a clinical examination, and those of scientific research, but after listing a dozen or so tests and procedures applicable respectively to each situation, they revert to the recommendation of a many-sided battery for practical testing. They list, as do the writer of (**12**), Christie (**38**), Haupt (**70**), Oblath (**106**), and Schaaf and Blum (**134**), several qualifications of a good practical test. Such a test must (a) be brief, (b) portable, (c) compact, (d) simple to administer, (e) accompanied by clear instructions for its administration, (f) intellectually simple to take, (g) easy to interpret, and (h) precise in its measurements and classifications; (i) it must not require color naming or other intellectual processes; (j) it must preclude simulation and malingering; (k) it must control the effects of adaptation and fatigue; (l) it should be inexpensive, but (m) not readily available to the general public. The writer of (**12**) feels that color naming should be required.

Amat (**7**), Haupt (**70**), and the writer of (**12**) are the only authors to recommend that a practical test parallel the color-perception requirements of the vocation or activity for which the applicant is being tested. It is the neglect of just this point by so many other writers that has led to much of the current confusion and disagreement.

Thus Verrey and Wölfflin (**148, 152, 165**) recommend almost normal performance on the anomaloscope as a requirement for admission to federal services. Amat (**7**) would require normal performance on the Stilling test and the anomaloscope for those railroad employees who would need normal color vision. Kalashnikov (**79**) uses the Cohn, Stilling, and Nagel pigment tests, and in doubtful cases, the anomaloscope. Vierling (**155**) favors Stilling's and Nagel's tests. Boström, Gruner and Meisling (**25, 100, 102**) report proposals made in the Scandinavian ophthalmological congresses to standardize legally and internationally the requirements for testing of applicants for transportation services. Stilling's and Ishihara's tests and a lantern test were recommended, along with periodic retests, and strict guarantees of the examiner's own normal color vision and testing abilities were called for. Bourdier and Schaaf (**29**) feel that such standardizations should await further scientific progress. Oblath (**106**) feels that each country should make its own legal stipulations. One finds Oblath, and also Jennings (**78**), stressing the importance of normal performance of applicants on pigment tests; Engelking (**55**) recommending also Hess' threshold determination procedure, perimetry, and the anomaloscope; Thompson (**145**) rejecting pigment tests, and requiring a lantern test; and the German railways altering their requirements when new tests are shown to detect defectives who met earlier test requirements.

In connection with marine service requirements the same fundamental difficulties are indicated by Chace's (35) criticism of the United States Public Health Service's testing in terms of a hexachromic color system (cf. Collins, 39). Furthermore, Old (108) expresses dissatisfaction at discovering that only 3.0% of the applicants for admission were shown to be defective, and recommends the adoption of more rigid entrance requirements.

For military aviation Constans (42) would require the passing of several pigment tests and a wool test; Bourdier and Schaaf (29) and Calajanni (30), the quick recognition of colors. Calajanni presents more clearly than other writers the actual demands made by aviation service upon color vision.

Ginestous (64), Bourdier and Schaaf (29), and Oblath (106) criticize "office tests" and "field tests" respectively for their leniency! Although Blum and Schaaf (20) find no discrepancies between the results of office and field tests, they would reserve the latter type of test for convincing the defective that he is defective. Verrey and Wölfflin (148) find marked discrepancies between the results and practical implications of the 2 types of test. The writer of (12) points out the genuine impracticability of an adequate field test and adheres to the sound recommendation that an office test should duplicate the actual field conditions most unfavorable to color vision.

There have been strong, persistent, and apparently justified objections to a requirement of normal color vision in automobile drivers (23, 24, 72, 162). Rather than eliminate hundreds of otherwise competent drivers, signal systems should be at once altered and standardized, and other aids to signal discrimination now available should be instituted.

Control by Signal Design. Many color-defective but otherwise capable automobile drivers, railroad men, seamen, and industrial employees resent the loss of their positions after a retest, especially when their employment record has been good and when the test standards have been changed. In the light of such protests Menacho (103) has recommended strongly a program of control through signal design. In this connection it may be noted that in the manner in which they are installed the geometric form signals used on the German railways require far less than normal visual acuity (cf. Schneider, 136). Somewhat different geometric signals are used by some American railways, but one may expect that increments in train speed will revive the problem of signals (cf. Ever-

sheim, **58**). Boström (**26, 27**) and Oblath (**106**) report the installation of acetylene-illuminated red and blue signals flashing at different rates at railway crossings in Sweden; in the absence of other controls such signals might be used even for train signals, since the colors can be discriminated at greater distances than can forms. However, dense fogs, important enough at slow train speeds, may ultimately force the replacement of ordinary signals by others which will provide an engineer with a signal or automatic control within the locomotive cab itself.

Mackald (**93**) reports the development and standardization of automobile traffic signals in America. Plimas (**119**) recommends that such signals differ in form as well as in color. T. D. Allen (**6**) suggests using 2 green lights for the "Go" signal, with perhaps a blinking "Caution" signal. The common practice of fusing the words, "Go," "Caution," and "Stop" into the colored glass filters used in prevailing signals renders them of some use to defectives at short distances. The bluish-green character of some contemporary "Go" signals and the tendency towards standardization of the location of the signals on the signal block are even more valuable to the defective driver. However, at greater distances, in such darkness that the outline of the signal block is invisible, and in the absence of cues from moving traffic and from traffic officers, the markedly defective driver has no dependable signal. Furthermore, during the daytime red "Stop" signals are invisible to about one out of every hundred male drivers (protanopes), so that such defectives cannot decide immediately whether a given signal is operating at the moment.

The present writer would recommend the installation of orange "Stop" signals, pure yellow "Caution" or "Wait" signals, and greenish-blue "Go" signals. Thus all signals used would have some light value even for protanopes; and those drivers who are unable to discriminate red and green from yellow and from each other would have at least a "yellow" cue to stop or wait and a "blue" cue to go ahead.

As a further guarantee of identification of signals by all color defectives there should be placed on the outside surface of each "Go" signal filter a sheet of light-polarizing glass, or "polaroid." Then there should be mounted on the front surface of the windshield of each vehicle operated by defectives needing such aids 2 small, juxtaposed, concave lenses, the forward surface of one of these lenses being covered with a sheet of polaroid whose plane of polarization is vertical to that of the polaroid in the "Go" signal. All signals

would then be visible through the plain lens, but only the " Stop " and " Caution " signals could be seen through the lens covered with polaroid. If a glance at the two lenses disclosed a light in each the cue would be, " Stop " or " Caution "; if the light were visible only in the plain lens the cue would be, " Go."

If polaroid windshields come into general use for the reduction of headlight glare, the plane of polarization of the polaroid on the " Go " signal filter should be parallel to that of the windshield, so that each signal would be visible through the windshield for normal drivers. Then the 2 lenses should be mounted beyond the end of the windshield on the driver's side of the vehicle so that they could be viewed through the non-polarizing side-window of the vehicle.

Such alterations of signal filters and installations of polaroid would permit identification of traffic signals under conditions which are both independent of color defects, and adequate for visibility alone. Standardized location of the " Stop " signal at the bottom of vertical signal blocks, and at that end of horizontal signal blocks which is nearer the middle of the road, would offer an additional cue at times during which the whole signal block is visible.

Control by Direct Treatment and Accessory Filters. Although Meisling (**101**) reports a defective individual who became normal for a few hours probably as a result of mussel poisoning, and suggests the possibility of the binding of some sensitizing dyes to the defective retina; and although Oloff (**109**) reports some temporary benefits from saline injections, the permanent cure of inherited defects of color vision is far from being a reality. Ahlenstiel, Sachs, and Streckfuss (**2**), Kern and Schöne (**80**), and Richardson-Robinson (**128**) report on the training of defectives to rely on the use of filters as aids to color discrimination. Dufour (**48**), Kern and Schöne (**80**), and Kirschmann (**82**) have made more notable contributions in this field. But the greatest progress has been made by Ahlenstiel (**2**) who stipulates certain requirements for corrective filters: they must be selective enough to induce sufficiently marked changes in brightness and saturation of colors, and they must have the same apparent brightness for the defective person (so that the induced changes will be more readily observable); they must be non-selective enough to pass light sufficient for good vision; they must be chosen to fit the particular defect at hand (as Kirschmann, **82**, suggests: with special regard for spectral limits and neutral zones); and they must be used under at least a minimal illumination of 900 to 1,000 lux both before and after training. Ahlenstiel's subject, after

wearing his filters, and after some instruction and practice, was able to discriminate and even to name most of the colors Ahlenstiel was using from Ostwald's *Color Atlas*. However, as Ahlenstiel's recommendation of minimal illumination implies, these findings must not be taken as predictive of absolutely normal color naming and discrimination of all transmitted and reflected light mixtures by even completely corrected defectives. Unpublished studies made by Virginia B. Jeffers at Bryn Mawr College, on color conversion and transformation, have shown clearly that the designation of hues, brightnesses, and saturations of pigments by normal subjects varies with the type of illumination and with the particular pigments used. She has suggested that Ahlenstiel's protanope would make noticeable errors in recognition and naming when he turned from the Ostwald colors to other pigments viewed under the varying conditions of everyday life. There is reason to believe that a corrected portrait painter would be found placing on the canvas pigments yielding for him the same brightness and saturation changes in his filters as do a certain portion of the sitter's features, but to a normal individual, appearing noticeably and undesirably different from the model.

However, some vocations and activities do not demand completely corrected color discrimination. Chapman (**36, 37**) describes red-free filters to be slipped over the upper part of drivers' spectacles. Tipping the head forward so as to view the signal block through the filter would cause red lights to appear black. The significant difficulty with such a system is that one out of every hundred drivers is so insensitive to long wave-lengths that during the day the red signals appear the same (black) whether they are viewed through the filter or otherwise, even when the light is on. Hence, these protanopes would receive no benefit from Chapman's filters, nor can they tell with the present system of traffic signals in America whether the red "Stop" signal is on or whether the signal block is not operating.

Glare protective glasses designed by Dr. Weidert and reported by Leiber (**87**) to have gained in some quarters in Germany an undeserved reputation for aiding color defectives, have been designated by both Leiber and the manufacturers as quite useless in this connection. Beach (**15**) reports beneficial effects of fitting totally color-blind subjects (presumably "photophobic") with perceptibly shaded lenses; however, it is obvious that such filters affect color discrimination in no particular fashion. Allen (**5**) reports beneficial effects of Vita glass spectacles for color-blind individuals, and detrimental effects of such spectacles for anomalous trichromats.

Acquired Defects. Cases of acquired defects have been reported steadily in connection with (a) drug and toxic poisoning; (b) diet deficiencies; (c) endocrine changes during pregnancy and menstruation, and other physiological changes; (d) abnormalities of the

retina, optic tracts, and central nervous system following diseases, operations, and congenital degenerative states; and (e) in connection with stable conditions and progressive changes of accommodation and of the media. As a rule, not only the immediate control and the scientific importance, but also the clinical significance of such findings is somewhat limited by the necessary reliance of ordinary clinical procedure upon relatively few cases, and by the practical restrictions of testing procedures used in clinics. The use of unstandardized perimetrical methods, or of a few pigment tests designed for detection of the marked defects, and the uncritical expression of findings in terms of classical typologies and theories tend actually to limit the scientific value of findings. Nevertheless, there are exceptions to the rule, and the provocativeness alone of many of the studies would justify their discussion.

Zeiner-Henricksen (166) reports on the action of a number of drugs, noting reduction of sensitivity for long wave-lengths and enhancement of it for short wave-lengths by alcohol (at least 30 cc.), cocaine, atropine, pilocarpine, and morphine; and just the reverse effects of strychnine, caffeine, pichrotoxine, quinine, and santonin. Rivet and Sambron (129) cite a case of intermittent chloropsy following treatment of barbituric poisoning with strychnine. The studies of Heine (71) and Marshall (98, 99) indicate that the effects of santonin vary with time and the conditions of vision, the latter author relating the action of santonin to the fatiguing of the eye with short wave-lengths. Sprague, White, and Kellogg (141), and Jackson and Zerfas (75) note the presence of other phenomena besides "yellow vision" after dosage with digitalis (cf. also Giesler and Wolff, 61).

In connection with the action of toxins Vinazzer (156) regards reduced red sensitivity as diagnostically significant in uremic poisoning. DiDonato (45) and Szware (144) report color field changes with vestibular infections. Boehmig (21) and Ellett (53) note effects accompanying general fatigue and exposure. Wechsler (160, 161) reports a case of carbon monoxide poisoning in which the subject could not recognize objects, but was able to distinguish and name their colors. Pilman (118) cites 34 out of 36 cases in which exposure to carbon monoxide led to contraction of the color fields.

Some diet deficiencies seem to be of significance: in opposition to Lundsgaard (92), who would relate hemeralopia and accompanying color defects to alcoholism, the findings of Fridericia and Holm (59) and of Candian (31) would indicate that Vitamin A deficiency is of greater importance in connection with such defects.

Holm (**74**) and Heine (**71**) would minimize the importance of menstrual changes for color vision, but Lorenzetti (**90**) demonstrates rhythmic reductions of the color fields during the pre-menstrual period. He finds also a gradual reduction during pregnancy and relates it to exaggeration of the pre-menstrual activity of the gonadal endocrines. Birnbacher and Klaften (**18**) suggest a relationship of hemeralopia to pregnancy and attendant visual susceptibility to the stronger sunlight of the summer months. Limper (**88**) and Puhl (**124**) submit evidence that individuals with dark pigmentation tend to be more sensitive to long wave-lengths and that seasonal changes in such sensitivity are more marked in dark than in light individuals.

In connection with diseases of the eye and optic tracts Koh (**84**) attempts to relate red-green defects to diseases of the optic nerve, and blue-yellow defects to retinal diseases. Heine (**71**) suggests a sequential involvement of these and other defects with several retinal diseases. The present writer feels that Lucanus'(**91**) attempt to be more specific regarding the relation of types of defect to loci of diseases is almost vitiated by his uncontrolled experimental differentiation of defects. Verrey's (**150, 151, 153**) commendable use of the anomaloscope is offset by his attempts to relate cases of acquired defects to certain classical types of inherited defects. On the other hand, Oloff (**109, 110**) demonstrates and regards as characteristic marked differences between the anomaloscopic performances of persons with acquired defects and those with inherited defects.

Alterations of red, green and white sensitivity and their relations to hypertension in glaucoma are noted by Verrey (**150**), Speciale-Picciche (**140**), and Wessely (**163**). Klainguti (**83**) demonstrates that the color defects accompanying retinitis pigmentosa are to be differentiated from total color-blindness in spite of the frequent presence of nystagmus in both types of defect. Halbertsma (**67, 68**), Waardenburg (**158**), and Wibaut (**164**) discuss the relation between inherited color-blindness and an inherited tendency for progressive retinal degeneration. Sedan (**137, 138**) and Oeller (**107**) report changes in red sensitivity both before and after cataract operations. Stahel (**142**) demonstrates that such changes are independent of ultra-violet stimulation, and proposes that they follow from the extended period of dark adaptation usually following cataract removal. Muncy (**105**) cites the possible prognostic value of contraction of color fields for neurosyphilis.

Concerning changes presumably more central in locus, Jennings (**77**) and Halpern and Haff (**69**) report color defects of various kinds accompanying cerebral injuries. Halpern and Haff's case, complicated by alcoholism and epilepsy, underwent partial

recovery from complete blindness, but manifested a permanent darkening of the visual field which was enhanced by faradization, and which was due presumably to the injury of tracts " conducting brightness impulses to the color centers." Pötzl (**122**) describes a 54-year old so-called amnestic color-blind subject with right sided hemianopsia, word-blindness, and with a rupture of blood vessels in the posterior region of the corpus callosum. This lesion resulted from arteriosclerosis and hypertension. Color equations and differential sensitivity for hue were normal, but tests demanding the perception of figures involving many colors (Stilling) were failed, thus pointing away from a " purely sensory " or " purely verbal " defect. Other responses indicated that the chief difficulty lay in the absence of color categories such that, *e.g.* 2 nuances of the same color were regarded as absolutely different, the perception of 2 identical colors as identical remaining unaffected. Turner and DeSilva (**147**) report on another individual somewhat of this type, who could discriminate but not recognize or classify colors. The perception of surface colors and two-dimensional forms was also affected. Purdy (**125**) reports that Turner and DeSilva's subject was able to develop a more analytic perception of forms and colors, and to acquire a more systematic appreciation of colors.

Rydin (**132**) confirms by a color discrimination experiment Hering and Hess' findings on increased absorption of short wavelengths by the lens of the eye with advancing age, and consistently manifested beyond the age of 80 years. Kravkov (**85**) concludes tentatively, and on the basis of an indirect analysis, that the yellow spot of subjects with light hair and eyes is relatively greenish, that of dark subjects, reddish. Blatt (**19**) found that 26.0% of a group of 429 anisometropes manifested some color defect. Loddoni (**89**) would partially relate myopia to protanomalous and hyperopia to deuteranomalous trichromasy at the level of chromatic aberration.

Gelb (**60**) cites the case of a wounded veteran with a progressive cerebellar lesion, in which a " set " for color would entirely destroy the object character of visual stimuli. "Advancing " and " retreating " of colors accompanied the color set.

BIBLIOGRAPHY

1. Adrogué, E., and Malbrán, J., Sobre un caso de acromatopsia parcial adquirida. *Rev. asoc. med. argent.*, 1933, **47**, 2713–2718.
2. Ahlenstiel, H., Sachs, E., and Streckfuss, H., Filtergebrauch bei Farbenblindheit. *Arch. f. Augenhk.*, 1928, **102**, 271–308.

3. ALAJMO, B., Sull' importanza del campo visivo dei colori per la diagnosi di "Sindrome chiasmatica." *Rassegna ital. d'ottal.*, 1932, **1**, 577–583.
4. ALBERTOTTI, G., La discromatopsia e gli artisti del pennello. *Gazz. internaz. med.-chir.*, 1926, **31**, Sez. 2, 333–441.
5. ALLEN, F., The Principle of Induction in Color Vision. *Amer. J. Ophth.*, 1932, **15**, 789–800.
6. ALLEN, T. D., Traffic Lights for Color Blind. *Amer. J. Ophth.*, 1934, **17**, 432–433.
7. AMAT, M. MARÍN, Propuesta de las condiciones que los agentes de la Compañia deben reunir en lo concerniente al aparato visual, a la visión y a la percepción de los colores. *Siglo medico*, 1932, **89**, 182–187.
8. ANON., Color Perception and Visual Acuity in Sailors. *J. Amer. Med. Assoc.*, 1923, **81**, 2130.
9. ANON., Traumatic Color Blindness. *J. Amer. Med. Assoc.*, 1926, **86**, 290.
10. ANON., Untersuchung der Kraftfahrer auf Farbenblindheit. *Zsch. f. Bahn- und Bahnkassenärzte*, 1930, **25**, 318.
11. ANON., Verfügung betreffend Wiederholungsprüfungen und Farbenunterscheidungsvermögen. *Zsch. f. Bahn- und Bahnkassenärzte*, 1925, **20**, 21.
12. ANON., Colour Vision Requirements in the Royal Navy. *Med. Res. Council Report*, No. 185. London: H.M. Stationery Office, 1933. Pp. 58.
13. BARKER, S. G., and HIRST, H. R., Color Problems in the Woolen Industries. *Proc. Opt. Conv.*, 1926, 189–210.
14. BARRIE, T. S., Color Sense in Amblyopic Eyes Associated with Strabismus Convergens. *Trans. Opt. Soc. United Kingdom*, 1923, **43**, 612–616.
15. BEACH, S. J., Total Congenital Color Blindness; General Medical Aspects with Report of Three Cases. *Trans. Sect. Ophth., Amer. Med. Assoc.*, 1928, June 11–15, 133–141.
16. BELL, JULIA, Colour Blindness. *Eugenics Lab. Mem.*, Univ. London, XXIII 2, p. II, p. 163. London: Cambridge Univ. Press, 1926.
17. BERRISFORD, P. D., Effects of Intense Light on the Retina. *Amer. J. Ophth.*, 1932, **15**, 1133–1137.
18. BIRNBACHER, H., and KLAFTEN, E., Die Hemeralopie der Schwangeren. *Zsch. f. Augenhk.*, 1923, **51**, 309–324.
19. BLATT, N., Farbensinnstörungen bei Anisometropie. *Arch. f. Ophth.*, 1924, **113**, 134–140.
20. BLUM, P., and SCHAAF, E., *Le Daltonisme.* Paris: Masson et Cie, 1929. Pp. 131.
21. BOEHMIG, —, Zentrale Farbensinnstörungen nach körperlichen Ausstrengungen. *Klin. Monatsbl. f. Augenhk.*, 1923, **70**, 397.
22. BOGORODITSKIY, N. J., Causes of Chromatopsia Frequently Observed After Cataract Extraction. *Sovet. vestnik. oftal.*, 1934, **5**, 576–578.
23. BONNER, W. E., Visual Requirements of Auto Drivers. *J. Amer. Med. Assoc.*, 1923, **81**, 1628.
24. BONNER, W. E., Monocular Color Blindness. *Amer. J. Ophth.*, 1926, **9**, 603–605.
25. BOSTRÖM, C. G., Om en mera effektiv färgsinneskontroll. *Hygiea*, 1926, **58**, 559–567.

26. Boström, C. G., Frågan om automobilförarnas färgsinne och därmed sammanhängande ifrågsatt ändring av signalsystemet vid järnvägsövergångarna. *Hygiea*, 1926, **58**, 335–345.
27. Boström, C. G., Signals at Railway Crossings. *Acta. Ophth.*, 1926, **4**, 65.
28. Bouasse, H., (Delagrave, Éd.) Vision et reproduction des formes et des couleurs. Paris.
29. Bourdier, H. N., and Schaaf, E., Les procédés d'examen de la vision des couleurs. *Bull. Soc. d'Opht. de Paris*, 1930, **42**, 501–779.
30. Calajanni, G., New Apparatus for Examination of Chromatic Sense. *Ann. di. ottal. e clin. ocul.*, 1931, **59**, 360–364.
31. Candian, F. L., Le seuil de l'excitation des couleurs simples du spectre dans les degrés normaux de passage vers les anomalies. *Arch. ital. de biol.*, 1931, **85**, 1–10.
32. Carsten, E., Ueber Hemeralopia idiopathica mit besonderem Hinblick auf Untersuchung und Behandlung. *Acta. Ophth.*, 1924, **2**, 225 ff.
33. Chance, B., Monochromatic Vision. *Trans. Amer. Ophth. Soc.*, 1930, **28**, 269–286.
34. Chance, B., Monochromatic Vision. *Amer. J. Ophth.*, 1931, **14**, 417–425.
35. Chace, A. E., Color Blindness in Industry. *J. Amer. Med. Assoc.*, 1926, **87**, 1258–1261.
36. Chapman, V. A., Safety Spectacles for Color Blind. *Trans. Sect. Ophth., Amer. Med. Assoc.*, 1933, 301–304.
37. Chapman, V. A., Safety Spectacles for Color Blind. *Wisconsin Med. J.*, 1935, **34**, 35–37.
38. Christie, W., Color Blindness in School Children. *Med. J. Australia*, 1930, **1**, 247–255.
39. Collins, G. L., *Color Blindness: Its Relation to Other Ocular Conditions and the Bearing on Public Health of Tests for Color Sense Acuity.* Public Health Bull., No. 2. Washington: Government Printing Office, 1918.
40. Collins, M., Anomalies and Defects of Colour Vision. *Dyer*, 1932, **67**, 633–634.
41. Collins, M., The Anomalies and Defects of Colour Vision. *Edinburgh J. Sci., Technol., & Photogr. Art* (*Trans. Roy. Scotland Soc. Arts*), 1932, **7**, 14–20.
42. Constans, G. M., Dyschromatopsia in Aviation Examinations with Report of Case. *U. S. Naval Med. Bull.*, 1926, **24**, 906–909.
43. Destounis, G., Délire d'interprétation chez un Daltonien. *Encéphale*, 1934, **29**, 271–276.
44. Deutschen Reichsbahn Gesellschaft, Farbentüchtigkeit der Reichsbahnärzte. *Zsch. f. Bahn- und Bahnkassenärzte*, 1928, **23**, 348.
45. DiDonato, D., Changes in Color Vision with Special Consideration of the Color Limen in Individuals Suffering from Diseases of the Inner Ear. *Arch. ital. di otal., rinol., e laringol.*, 1923, **34**, 221 ff.
46. Dor, M., Un cas de dyschromatopsie aigue. *Presse Méd.*, 1923, **31**, (11), 491.
47. D'Osvaldo, E., Light and Color Sense in Nephritis; No Ophthalmoscopic Changes; Normal Visual Acuity. *Lettura oft.*, 1933, **9**, 503.

48. DUFOUR, M., L'emploi des filtres colorés et la vision des coleurs. *Ann. d'ocul.*, 1924, **161**, 801.

49. DUGGAN, J. N., and NANANATI, B. P., A Case of Quinine Amblyopia with Central Colour Scotoma of One Eye and Total Blindness of the Other. *Brit. J. Ophth.*, 1931, **15**, 164–166.

50. EDRIDGE-GREEN, F. W., The Effect of Blood in the Retina on Color Equations. *Rep. Brit. Assoc. Adv. Sci.*, 1923, **90**, 480.

51. EDRIDGE-GREEN, F. W., First Recorded Cases of Colour Blindness. *Rep. Brit. Assoc. Adv. Sci.*, 1927, **95**, 370.

52. EDRIDGE-GREEN, F. W., Vision and Color Vision. *Post-grad. Med. J.*, 1934, **10**, 346–354.

53. ELLETT, —, Color Sensations of Uncertain Origin. *Amer. J. Ophth.*, 1926, **9**, 846.

54. ENGELKING, E., Untersuchungen an Farbenblinden. *Münch. med. Woch.*, 1924, **71**, 1257.

55. ENGELKING, E., Ueber die Bedeutung von Schwellenwertsbestimmungen für die praktische Beurteilung des Farbensinnes. *Klin. Monatsbl. f. Augenhk.*, 1925, **74**, 68–93.

56. ENGELKING, E., and KÖLLNER, —, *Die Abweichungen des Farbensinns. Photorezeptoren.* Berlin: Springer, 1929.

57. ENSLIN, —, Ueber Goethes Farbenlehre. *Klin. Monatsbl. f. Augenhk.*, 1925, **75**, 778.

58. EVERSHEIM, —, Zur Frage der einseitigen Farbensinnstörungen. *Zsch. f. Bahn- und Bahnkassenärzte*, 1932, **27**, 298–301.

59. FRIDERICIA, L. S., and HOLM, E., Experimental Contribution to the Study of the Relation Between Night Blindness and Malnutrition. *Amer. J. Physiol.*, 1925, **73**, 63–78.

60. GELB, A., Ein Beitrag zur Psychopathologie der Farbenwahrnehmung. *Zsch. f. Psychol.*, 1933, **129**, 271–281.

61. GIESLER, F., and WOLFF, K., Beitrag zur Xanthopsie nach Digitalis. *Klin. Monatsbl. f. Augenhk.*, 1927, **79**, 203–209.

62. GIL, R., and ADROGUÉ, E., Estadistica sobre la frecuencia del daltonismo entre los aspirantes a ingresar a la Policia de la Capitol Federal. *Rev. d. l. Asoc. Med. Argent.*, 1933, **47**, 3229–3231.

63. GILBERT, —, Examination for Color Blindness by Color Blind Physicians. *Zsch. f. Bahn- und Bahnkassenärzte*, 1927, **22**, 127–130.

64. GINESTOUS, E., Critique au point de vue hygiénique de l'examen visuel et des conditions d'aptitude visuelle des employés du service actif des chemins de fer. *Ann. d'Hyg.*, 1923, **1**, 311–321.

65. HAAS, E., and BOURGUIGNON, G., Un cas de dyschromatopsie simulée. *Bull. Soc. d'Opht. de Paris*, 1931, 353–359.

66. HÄBICH, T., Farbenblindheit und Berufstauglichkeit. *Industr. Psychotechn.*, 1927, **4**, 249–251.

67. HALBERTSMA, K. T. A., Over erfelijke ontaarding van de gele vlek gepaard met kleurenblindheid. *Nederl. Tijdsch. v. Geneesk.*, 1927, **71**, 2-B, 2056–2068.

68. HALBERTSMA, K. T. A., Over de beteeknis van veranderingen in de gele vlek in verband met erfelijke albinisme, kleurenzinstoornis en aangeboren nystagmus. *Nederl. maandschr. v. Geneesk.*, 1931, **17**, 611–634.

69. HALPERN, F., and HAFF, H., Kasuistische Beiträge zur Frage der cerebralen Farbenblindheit. *Zsch. f. d. ges. Neurol. u. Psychiat.*, 1929, **122**, 575–587.

70. HAUPT, I., Color Blindness Tests; A Survey of the Literature with Bibliography to 1928. *J. Gener. Psychol.*, 1930, **3**, 222–267.

71. HEINE, L., Ueber erworbene Anomalien des Farbensinnes. *Naturwiss.*, 1924, **12**, 41–46.

72. HESSBERG, R., Die Bedeutung der Farbentüchtigkeit im öffentlichen Verkehr. *Zsch. f. Augenhk.*, 1929, **69**, 315–320.

73. HESSBERG, R., Ueber erworbene Farbensinnstörungen. *Zsch. f. Bahn- und Bahnkassenärzte*, 1929, **24**, 95–99.

74. HOLM, E., Contractions of the Visual Field During Pregnancy. *Acta Ophth.*, 1924, **2**, 92–96.

75. JACKSON, H., and ZERFAS, L. G., Yellow Vision Associated with Digitalis Poisoning. *Boston Med. & Surg. J.*, 1925, **192**, 890–893.

76. JENNINGS, J. E., Monocular Color Blindness Noticed After a Blow on the Head. *Amer. J. Ophth.*, 1925, **8**, 384–385.

77. JENNINGS, J. E., Test for Color Perception. *Amer. J. Ophth.*, 1926, **9**, 221.

78. JENNINGS, J. E., Evaluation of Pseudo-isochromatic Tests for Detection. *Amer. J. Ophth.*, 1931, **14**, 952–958.

79. KALASHNIKOV, V. P., Recognition of Color Blindness According to the Methods of Cohn, Stilling and Nagel. *Sovet. vestnik oftal.*, 1932, **1**, 318–328.

80. KERN, B., and SCHÖNE, F., *Sonderstellung gewisser Farbtöne und Heilbehandlung von Farbenschwäche.* Stuttgart: Enke, 1925. Pp. 163.

81. KEYSER, G. W., Requirements of Eyesight and Color Sense in Medical Offices of the Army. *Norsk. Tidsskr. f. Mil.-Med.*, 1929, **33**, 29–39.

82. KIRSCHMANN, A., *Psychologische Optik. Handbuch der biol. Arbeitsmethoden, Abderhalden.* Berlin: Urban & Schwarzenberg, 1927. Pp. 837–1110.

83. KLAINGUTI, R., Farbensinnstörung bei *retinitis pigmentosa* und totale Farbenblindheit. *Schweiz. med. Woch.*, 1923, **53**, 910–912.

84. KOH, C., Disturbances of the Central Color Sense with Various Diseases of the Eye. Nippon, *Gankaki Zasshi*, Aug.–Oct., 1922.

85. KRAVKOV, S. W., Ueber die Lichtabsorption im gelben Flecke des lebenden Auges. *Pflüg. Arch. f. d. ges. Physiol.*, 1925, **210**, 781–789.

86. LAHY, T. M., *La selection psychophysiologique des travailleurs.* Paris: Dunod, 1927.

87. LEIBER, F., Steigerung der Farbenwahrnehmung durch Lichtfilter. *Central-Zeitung für Optik und Mechanik*, 19—, —, 104–106.

88. LIMPER, K., Individuelle Unterschiede des Farbensinnes, insbesondere die Formen der Anomalie und Farbenblindheit, und ihre Beziehungen zur Gesamtpersönlichkeit. *Zsch. f. Psychol.*, 1931, **121**, 178–249.

89. LODDONI, G., Color Perception in Cases of Ametropia. *Ann. di ottal. e clin. ocul.*, 1929, **57**, 539–549.

90. LORENZETTI, F., Contributo allo studio del campo visuo e del senso cromatico della donna durante i periodi catameniale e puerperale. *Annali di ostet. e ginec.*, 1926, **48**, 765–782.

91. LUCANUS, —, Erworbene Gelb-Violett-Blindheit und ihre Erkennung. *Klin. Monatsbl. f. Augenhk.*, 1925, **75**, 77–87.
92. LUNDSGAARD, K. K. K., On Night-Blindness and Other Eye Complications in Chronic Alcoholists. *Acta. Ophth.*, 1924, **2**, 112–124.
93. MACKALD, K. W., Traffic Control by Color Signals. *Trans. Illum. Engin. Soc.*, 1927, **22**, 509–532.
94. MACKENZIE, R., A Peculiar Visual Experience. *Nature* (London), 1932, **130**, 888–889.
95. MACKLIN, M. T., Color Sensitivity in Medical Students. *Canad. Med. Assoc. J.*, 1933, **29**, 302–303.
96. MARINESCO, —, and (MME.) NICOLESCO, —, Un cas de parkinsonisme accompagné de crises oculogyres et d'hallucinations coloreés. *Rev. neurol.*, 1932, **2**, 691–693.
97. MARINESCO, G., Visions coloreés produit par la mescaline. *Presse méd.*, 1933, **41**, 1864–1866.
98. MARSHALL, W., A Study of Santonin Xanthopsia. *J. Pharm. & Exper. Therap.*, 1927, **30**, 361–388.
99. MARSHALL, W., Color Vision After Intravenous Injection of Santonin. *J. Pharm. & Exper. Therap.*, 1928, **32**, 189–203.
100. MEISLING, A., Om Farvensans og Farvensansprøven. Forslag til faellesnordiske Regler for Farvensansprøven. *Hospitalstidende*, 1924, **67**, 93–96.
101. MEISLING, A., Color Sense and Color Sense Tests. *Amer. J. Ophth.*, 1926, **9**, 558–559.
102. MEISLING, A., GRUNER, —, and BOSTRÖM, —, Farbensehen und Farbensinnprüfung als Einleitung zur Diskussion über gemeinschaftliche nordischen Proben. *Klin. Monatsbl. f. Augenhk.*, 1926, **76**, 288.
103. MENACHO, M., Les exigencias de la industria respecto a la mano de obra en relacion con la aptitud visual. *Arch. de oftal. hispano-amer.*, 1931, **31**, 135–147.
104. MILES, W., and CRAIG, H., Color Blindness in Dry Goods Salesmen. *Person. J.*, 1930–1931, **9**, 437–449.
105. MUNCY, W. M., Contraction of Color Fields in Neurosyphilis. *Rhode Island Med. J.*, 1935, **18**, 9.
106. OBLATH, O., *Color Vision Tests.* (Trans. by J. Marshall.) London: P. S. King & Son, 1929. Pp. 48.
107. OELLER, —, Erythropsie. *Klin. Monatsbl. f. Augenhk.*, 1924, **73**.
108. OLD, E. H. H., Color Blindness. *U. S. Naval Med. Bull.*, 1927, **25**, 253–266.
109. OLOFF, H., Ueber erworbene Farbensinnstörungen. *Klin. Monatsbl. f. Augenhk.*, 1932, **88**, 853–854.
110. OLOFF, H., Ueber erworbene Farbensinnstörungen. *Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch.*, 1932, **49**, 372–374.
111. PARSONS, J. H., Colour Vision and Its Anomalies. *Brit. J. Ophth.*, 1930, **14**, 97–114.
112. PEAR, T. H., A Note on the Selection of Color Workers. *Brit. J. Physiol. Optics*, 1933, **7**.
113. PECH, J. L., Experimental Daltonism. *Presse méd.*, 1930, **38**, 1736.

114. PICKARD, R., Red Field and Optic Disk Resistance in Glaucoma and Allied Conditions. *Proc. Roy. Soc. Med.*, 1930, **23**, 845–854.

115. PIERCE, W. O'D., Individual Differences in Normal Color Vision. (A Survey of the Recent Experimental Work, 1910–31.) *Med. Res. Council Report, No. 181.* London: H. M. Stationery Office, 1933. Pp. 96.

116. PIERCE, W. O'D., The Selection of Color Workers. *Human Factor*, 1934, **8**, 286–290. (Also: *J. Oil Chem. Assoc.*, 1931, **14**, 90 ff.; *Rep. Brit. Assoc. Adv. Sci.*, 1932, **99**, 376 ff.)

117. PIERCE, W. O'D., *The Selection of Color Workers.* New York: Pitman, 1934. Pp. xi+134.

118. PILMAN, H., The Effect of Carbon Monoxide Poisoning on the Visual Organ. *Sovet. vestnik. oftal.*, 1934, **4**, 433–440.

119. PLIMAS, P. A., Ocular Examination of Chauffeurs and Motormen. *Sovet. vestnik. oftal.*, 1934, **2**, 172——.

120. PODESTA, H., Sehleistung und Farbensinn bei der Münsterschen Studentenschaft. *Münch. med. Woch.*, 1924, **71**, 1637–1639.

121. POLOMAR, C. F., Vision des couleurs et aptitude professionelle. *Ann. Secc. Oriental Profess. Escuela,* Trab. 2, 1929.

122. PÖTZL, O., Ueber die amnestische Farbenblindheit. *Med. Klin.*, 1925, **21**, 186.

123. PRESTON, F. E., Colour Blindness in a Woman. *Proc. Roy. Soc. Med.*, 1931, **24**, 756.

124. PUHL, E., Die individuellen Differenzen des Farbensinnes in ihrer Beziehung zur Gesamtpersönlichkeit. *Zsch. f. Sinnesphysiol.*, 1932, **63**, 1–37.

125. PURDY, D. McL., Abnormal Totalizing Perception. *Psychol. Bull.*, 1934, **31**, 599.

126. REEDER, J. C., Inversion of Color Fields in Cardiospasm. *J. Iowa State Med. Assoc.*, 1928, **18**, 470 ff.

127. REIM, H., Visual Acuity and Color Perception of Railway Employees. *Amer. J. Ophth.*, 1927, **10**, 418–421.

128. RICHARDSON-ROBINSON, F., A Case of Color Blindness to Yellow and Blue. *Amer. J. Psychol.*, 1923, **34**, 157–184.

129. RIVET, L., and SAMBRON, J., Amaurose toxique passagère suivre de chloropsie à la suite d'un coma barbiturique traite par la strychnine. *Bull. et mém. Soc. méd. d'hôp. de Paris*, 1934, **50**, 17–19.

130. ROHRSCHNEIDER, —, Apoplektiform entstandene totale Farbenblindheit. *Klin. Woch.*, 1928, **24**, 1153 ff.

131. ROHRSCHNEIDER, —, Ein Fall von apoplektiform entstandener doppelseitiger totaler Farbenblindheit. *Klin. Monatsbl. f. Augenhk.*, 1928, **80**, 402.

132. RYDIN, H., De la capacité de distinguer, aux différents ages de la vie, les radiations vertes ayant une longuer de 539 mμ et celles vert-bleuatre de 500 mμ. *C. r. Soc. biol.*, 1927, **96**, 818–820.

133. SAMOILOV, A. Y., Clinical Aspect; Dichromatopsia Compared with Normal Trichromatopsia. *Sovet. vestnik. oftal.*, 1932, **1**, 17–22.

134. SCHAAF, E., and BLUM, P., Étude comparative des différents procédés employés pour la recherche du daltonisme et presentation de tests nouveaux. *Bull. Soc. d'Opht. de Paris*, 1925, 516–537.

135. SCHAAF, E., and BLUM, P., Considerations sur la capacité visuelle minima nécessaire aux cheminots, automobilistes, et professions similaires. *Bull. Soc. d'Opht. de Paris,* 1927, 575–585.

136. SCHNEIDER, R., Color Blindness for Signals in Railway Employees. *Zsch. f. Bahn- und Bahnkassenärzte,* 1928, **23**, 50–59.

137. SEDAN, J., Recherches sur la chromatopsie périphérique de l'aphaque. *Rev. d'oto-neuro-ocul.,* 1927, **5**, 173–180.

138. SEDAN, J., Recherches sur la chromatopsie périphérique de l'aphaque. *Marseille méd.,* 1926, **63**, 1823–1831.

139. SPECIALE-CIRINCIONE, F., Il senso cromatico ed il suo esame clinico. *Ann. di. ottal. e clin. ocul.,* 1924, **51**, 137–152.

140. SPECIALE-PICCICHE, P., Threshold of Chromatic Excitation (Red and Green of Spectrum) in Glaucoma; Use of Chromatoscope in 15 Cases. *Ann. di ottal. e clin. ocul.,* 1927, **55**, 884–900.

141. SPRAGUE, H. B., WHITE, P. D., and KELLOGG, J. F., Disturbances of Vision Due to Digitalis: Review of the Literature and Report of Cases. *J. Amer. Med. Assoc.,* 1925, **85**, 716–720.

142. STAHEL, W., Experimentelles über Erythropsie bei Aphakischen. *Arch. f. Ophth.,* 1934, **132**, 1–9.

143. STRUYCKEN, H. L. J., Merkwürdige Signallichter. *Klin. Monatsbl. f. Augenhk.,* 1926, **76**, 729.

144. SZWARE, —, Ohr und Farben. *Klinika Oczna,* 1924, **2**, 116 ff.

145. THOMPSON, J. H., Color Myopia. *Med. Herald* (Kansas City, Mo.), 1923, **42**, 274.

146. TOCANTINS, L. M., and JONES, H. W., Defective Color Vision and Its Handicaps in Medicine (Tests and Medical Students). *Amer. J. Med. Sci.,* 1933, **185**, 243–249.

147. TURNER, W. D., and DESILVA, H. R., The Perception of Color and Contour; An Unusual Abnormal Case. *Amer. J. Psychol.,* 1934, **46**, 537–557.

148. VERREY, A., and WÖLFFLIN, E., Die Prüfung des Farbensinns bei den Schweizen Bundesbahnen. *Klin. Monatsbl. f. Augenhk.,* 1923, **71**, 228–229.

149. VERREY, A., L'examen de la perception colorée et nos administrations fédérales. *Rev. gén. d'opht.,* 1923, **37**, 381–398.

150. VERREY, A., Affections du nerf optique et perception des couleurs. *Bull. et mém. Soc. franc. Opht.,* 1926, **39**, 245–264.

151. VERREY, A., Afecciones del nervo óptica y percepción de los colores. *Archivos de oftal.,* 1926, **26**, 373–385.

152. VERREY, A., Quelque notes encore sur l'examen de la perception des couleurs et les chemins de fer fédéraux. *Rev. gen. d'Opht.,* 1926, **40**, 149–153.

153. VERREY, A., Variation du sens chromatique dans les dyschromatopsies acquises; equivalence de ces états avec les diverges formes de dyschromatopsie congenitale. *Arch. d'Opht.,* 1926, **43**, 612–623.

154. VIERLING, —, Ein Fall von Simulation. Ein physiologische und psychologische Studie. *Zsch. f. Bahn- und Bahnkassenärzte,* 1925, **20**, 117–135.

155. VIERLING, —, Die Seh- und Farbensinnprüfung. *Zsch. f. Bahn- und Bahnkassenärzte*, 1932, **27**, 171–186.

156. VINAZZER, E., Rotsehen als Frühsymptom bei urämischen Erkrankungen. *Med. Klin.*, 1929, **25**, 1395–1396.

157. VOGELSANG, K., Störungen der Licht- und Farbensinnes. *Med. Klin.*, 1931, **27**, 19–20.

158. WAARDENBURG, P. J., Kleurenblindheid, netviesafwijking en erfelijkheid. *Nederl. Tijdsch. v. Geneesk.*, 1927, **71**, 2-B, 2292–2293.

159. WAARDENBURG, P. J., Zu meiner Mitteilung über "Kombination von angeborener Achromatopsie und atrophia retinae pigmentosa." *Klin. Monatsbl. f. Augenhk.*, 1930, **85**, 270–271.

160. WECHSLER, I. S., Cécité corticale avec conservation de la vision colorée consécutive à une intoxication par l'oxyde de carbone. La question de la vision colorée, de l'agnosie des couleurs et de leur localization. *Rev. neurol.*, 1931, **2**, 490.

161. WECHSLER, I. S., Partial Cortical Blindness with Preservation of Color Vision. Report of a Case Following Asphyxia (Carbon Monoxide Poisoning?); a Consideration of the Question of Color Vision and Its Cortical Localization. *Arch. of Ophth.*, 1933, **9**, 957–965.

162. WECKERS, L., Aptitude psycho-physiologique des conducteurs d'automobiles. *Arch. d'Opht.*, 1929, **49**, 717 ff.

163. WESSELY, —, Ueber die Bedeutung der Farbenperimetrie beim Glaukom. *Klin. Monatsbl. f. Augenhk.*, 1927, **79**, 811–812.

164. WIBAUT, F., Eenige opmerkingen over de erfelijkheid van de ontvaarding der gele vlek gepaard met kleurenblindheid. *Nederl. Tijdsch. v. Geneesk.*, 1927, **71**, 2-B, 2293–2295.

165. WÖLFFLIN, E., Die Farbensinnprüfung und unsere eidgenössischen Verwaltungen. *Klin. Monatsbl. f. Augenhk.*, 1923, **71**, 229–230.

166. ZEINER-HENRICKSEN, K., Action of Alcohol and Certain Other Poisons on Color Perception. *Norsk Magazin for Laegevidskapen*, Supplement: July, 1927, 1–120.

CARR, H. A., *An Introduction to Space Perception.* New York: Longmans, Green and Company, 1935. Pp. xi+413.

Intended as a textbook for a college course this book does not profess to be a complete treatise. Its function is to arouse in the student an interest in the fundamental problems of perception. Innumerable facts are given to make the student aware of the intricacies of the subject, and he is left with a long array of unanswered questions which should arouse his scientific curiosity if he has any. These questions cluster around three topics: (1) nativism, (2) dualism and representation, and (3) Carr's own "motor" theory. It is asserted in the introduction that the importance of the problem of nativism and empiricism has been greatly exaggerated, and the closing lines of the book repeat the assertion, yet the problem recurs again and again. On the whole the answer offered the student is nativistic in the sense that learning, although its importance is always recognized, is generally relegated to a secondary rôle, and the possibility, at least, that the organization is innate is always entertained. At times the slant toward nativism is surprisingly marked as when it is concluded not only that the relation of correspondence between the foveas is innately conditioned, but also that "we are probably justified in assuming that this is also true for all other pairs." This conclusion overlooks the possibility (much more consistent with the author's motor theory) that the gradient of sensitivity toward the fovea will insure that each eye will move in such a way as to bring the image of the fixated object upon the fovea, thus assuring correspondence of these points, and that other corresponding points are determined with respect to the foveas. The final conclusion is that "any discussion of the native or empirical nature of space in general is a futile waste of time and energy. Each particular coördination must be considered separately."

In contrast to this judicious attitude toward nativism, there is a violent and consistent attack on dualism. "We must distinguish between the stimulating object on the one hand and the resulting stimulus on the other." Stimuli are "the vibrating conditions present at the sensitive surfaces." "We do not perceive our own retinal

images." "We merely conceive of the image as we would perceive it if it were visible." And so, after 28 pages on "upright vision" we find the conclusion that "the phenomenon of visual inversion immediately disappears when we discard the dualistic position." If one asks why so much space is devoted to this phantom problem (and several others, horopter, autokinesis, etc.) the answer is to be found in the pedagogical purpose of the book. Large concessions are made to the naïveté of the student in order to lead him on to discover the implications of his uncritical assumptions.

The third general issue is Carr's "motor theory." This theory has evidently given direction to much of Carr's own work and has largely determined the selection of the material which has entered into the book. At times it leads him into extreme positions, as when he concludes that "perception of a moving light is mediated by eye-movements," and that innervation is responsible for the autokinetic phenomenon. Throughout, innervation is made to carry a heavy load of responsibility. Movements and habitual patterns of movement with postural stimuli constitute the common denominators among sensory functions and between them and successful manipulation, which is in turn the final test of correct perception. The argument is well supported. On the other hand one is impressed by the failure to include what seems to be good evidence. Thus, while noting the importance of head movements in auditory localization no allowance is made for the arbitrariness of the usual experiments in which the head is prevented from turning. A consistent motor theory would want to know what happens when the head is free to turn so as to equalize both phase and intensity at the two ears. Similarly in the case of perceiving direction visually, the restriction of head and eye movements necessary in many set ups is accepted without comment. So too, monocular parallax is listed very casually under "accessory aids" in distance perception although the absolute necessity for firm head-rests in experiments supports every-day experience in indicating that this form of motor adjustment is of primary importance.

Seen movement "is but the perception of a continuous change in location." Abrupt changes, moving pictures, and "much experimental work" devoted to the spatial and temporal limits of seen motion are dismissed in a few lines. The student will not learn anything at all about the phi-phenomenon. Perhaps all of this is explainable in terms of a bias against the dynamic and in favor of the static or geometrical. In this light, size-constancy also proves resistant to

geometrical thinking. Although it is not ignored (except that the name is not used) the discussion of it is not clear.

The beginning student for whom this book is intended will find ample material and will be confronted with some of the most important problems of the psychology of perception. The psychologist will find so much material in the book that he will be annoyed at not finding the small remainder. For the sake of the student who is to go to the sources, the references are largely confined to the English language, but this hardly explains the neglect by the author himself of whole segments of the published work on topics which he writes about.

The index of such a book has a real function in the service of the young student who wishes to review, and of the older student who wants to know what the author has to say on a particular topic. An index should not be prepared mechanically but should be made by someone who is aware of the relative importance of the several terms used in the book. In this case the index does not give: chiasma; parallax or monocular; telestereoscope; phakoscope; motion, moving, or pictures or movement; accommodation; shadow; disparity; intervention. All of these are found in the text and a few are found in the index itself as sub-entries under another term. The index does not give, and careful perusal does not discover in the text: dominance, acuity, minimum visibility, phi, Gestalt, saccadic, stroboscope.

Whatever the omissions, Carr has packed 400 pages full of material, plainly written, without a word of padding, making a valuable text and an invaluable source of information for every student of perception.

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• MAIER, N. R. F., and SCHNEIRLA, T. C., *Principles of Animal Psychology.* New York: McGraw-Hill Book Company, 1935. Pp. xiii+529.

This volume is one of the finest psychological textbooks that the reviewer has met. It is an unusually careful and clear piece of writing, the mechanical features of the book are superb, and the handling of the material is so successful from the standpoint of bringing out the theoretical significance of the research covered that the book is a fascinating one to read.

It is surprising that in the last few years there have appeared in animal psychology, a field inadequately represented for so long, four

such notable texts as Munn's *Animal Psychology,* Moss *et al.*'s *Comparative Psychology,* Warden, Jenkins, and Warner's one-volume and three-volume works on *Comparative Psychology,* and the present volume by Maier and Schneirla.[1] Furthermore, it is notable (and most fortunate) that each of these texts has used a distinctive approach in organizing the material in this field—Munn by a comprehensive and critical utilization of the research on the most-studied animal, the rat; Moss *et al.* by covering the whole range of animal life, but organizing the material solely on the basis of its relationship to the various main psychological problems such as maturation and motivation; Warden, Jenkins, and Warner by covering the whole animal kingdom, as with Moss, but cataloguing the material in a rigid form that drastically subordinates theoretical interpretation to the ideal of systematic classification; and Maier and Schneirla's book lying, as it were, within the triangle marked off by these three other works.

Maier and Schneirla's book resembles that of Warden, Jenkins, and Warner in that the discussion follows the course of evolutionary development, starting with plants and protista and working up to mammals. But with this one feature, the resemblance stops. The outstanding differences are these: (1) about 45% of Maier and Schneirla's book is devoted to mammals, whereas in Warden, Jenkins, and Warner's *Introduction to Comparative Psychology, e.g.* less than one-fourth of the book is devoted to the methods and results of research on mammals; (2) the discussion of methods is not segregated in a few introductory chapters, but is scattered through the book in connection with particular topics, the authors holding that methods are so essentially linked to the problems and animals to which they are related that there is little to be gained by a more abstract discussion trying to cover this matter for all animals; and (3) rather than mechanically following the same outline for phylum after phylum, Maier and Schneirla have centered the discussion of each phylum around the problem of the new steps in the unfolding of behavior that are represented in that phylum. The stress throughout is on problems and hypotheses and principles, and not upon species or phyla as such. Thus Chapter I, on " Plants and Protista,"

[1] To this list of four, one almost might add the *Handbook of Social Psychology,* edited by Murchison, because six of its chapters, with a total of 234 pages, cover so extensively the problem of social behavior in animals, which is not dealt with to any great extent in any of these other books. Tolman's *Purposive Behavior in Animals and Men* also might be recalled for its detailed discussion of the nature of animal learning.

discusses the fundamental characteristics of behavior that are present even in such simple forms. The second chapter, on the simplest multicellular animals, deals chiefly with the problem of integration of activities in such more complicated organisms. And so on through the eleven chapters of Part I. The result is a group of chapters which are fascinating to follow, and which, the reviewer believes, represent an unusually high type of scientific thinking. Parts II and III deal with mammalian behavior, the three chapters in Part II dealing respectively with natively determined behavior, discrimination of stimuli, and neural mechanisms; and the six chapters in Part III dealing respectively with a general analysis of learning, the methods of studying learning, the analysis of maze learning, factors determining the efficiency of performance, factors determining the rate of learning, and higher mental processes.

The authors have made no attempt to give an exhaustive record of research in animal psychology. Instead, they decided, apparently, that it would be better to give relatively complete accounts of the best and most representative studies, judging merit particularly on the basis of theoretical significance, rather than to give a crowded record covering a great many studies. This characteristic of the book makes it vastly more enjoyable to read, and should make it much more effective as a means of fostering a critical and inquiring approach in the minds of students. There is no scarcity of empirical material, however—the bibliography is confined to references discussed in the text, and yet it includes 661 references.

In its mechanical features the book is a model. The analytical table of contents gives a clear and thought-provoking outline of the book. The bibliography of 661 titles is complete and very well printed; and, *mirabile mirabilium,* the references are cited in the text by author and year of publication as, "Lyon (1924)," rather than by some one of the unilluminating means of reference so commonly employed in psychological literature. Only a small portion of the book is consumed in giving anatomical and physiological information. The limitation of this material is made possible partly by the fact that the emphasis of the book is primarily behavioral, rather than physiological, and partly by the efficient typographical form in which such material is given. Near the start of the discussion of each phylum, a table gives, in fine print, a concise tabulation of the main facts regarding the receptor equipment, conduction system, and action equipment of that phylum. Other non-psychological material, such as the description of the main types of animals found in any given

phylum, is given in footnotes rather than in the text. Consequently, such material is in an optimal form for easy reference, and does not obstruct the reading of the text as such. Unnecessary technical terms have really been avoided; and where technical terms have been considered necessary, they are defined in footnotes. The illustrations are numerous and well-selected. Only one defect is noticeable in this matter of mechanical set up—namely, that a number of the figures are labeled by letters or other symbols explained in the subtitles, rather than being labeled directly. It is high time this custom was outlawed.

The one major adverse criticism I would make of the book concerns its treatment of learning in Part III. The authors define learning as the impressing of associations between contiguous experiences in cases where the contiguity is determined by the environment (the latter part of this definition, it might be noted parenthetically, is aimed at excluding thinking or reasoning from the field of learning, the contiguity in the latter case being more definitely the contribution of the animal). In addition to learning as thus defined, the authors recognize "selection of response" as another chief phase of what goes on in learning experiments. This selection of response (or, as some might prefer to call it, "discovery of solutions") seems to me an exceedingly important thing, and would certainly be included under learning by most psychologists. But, whether or not included under learning, this selection of response is theoretically just as important and just as deserving of attention as is the impressing of associations. Yet, so powerful are words and definitions and so frail the mind of man that, having defined learning in the way indicated, the authors pay almost no attention to the matter of discovery of solutions. Conditioned response experiments are described as the type *par excellence* of learning method, on the theory that in them not only is the stimulus situation controlled by the experimenter, but also the response is selected for the animal, and learning as a matter of impressing of associations can be studied in relative purity. And so on. There are some fine chapters in this Part III, but from the standpoint of its theoretical adequacy it is warped and lopsided at a number of points.

One other feature of Part III which I consider a bit regrettable is that almost two-thirds of the references in this part, and perhaps more than that proportion of space, are devoted to the rat. Particularly in view of the fact that this animal has been represented so adequately in Munn's book, it seems that the value and interest of

this volume would have been increased by a greater relative stress on other mammals. Correlated with this stress, perhaps, is the fact that in the chapters on mammalian behavior there is a noticeable lack of naturalistic material such as is used with great effectiveness in many chapters in Part I.

Probably not all psychologists would object to these characteristics of the book. But, even counting these as rather definite faults, the reviewer nevertheless considers this book, from start to finish, one of the most lucidly written volumes he has seen, and one of the most mature and stimulating in its theoretical handling of research material.

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WARDEN, CARL J., JENKINS, THOS. N., and WARNER, LUCIEN H., *Comparative Psychology. Volume I: Principles and Methods.* New York: The Ronald Press Company, 1935. Pp. x+506.

This is an excellent handbook of comparative psychology. Its scope and contents are suitable for senior and graduate students who have a good foundation in biology and psychology. The language is easy-going, considering the fact that much of the book is technical in character, and the style and organization are such as to sustain the interest of qualified readers. The chapter titles are: (1) "The Development of Modern Comparative Psychology"; (2) "The Natural Science Viewpoint in Biology"; (3) "The Biological Foundations of Comparative Psychology"; (4) "The Classification and Analysis of Behavior"; (5) "Methods of Testing Receptive Capacities"; (6) "Methods of Testing Reactive Capacities"; and (7) "Comparative Morphology and Psychology." There are 141 illustrations, including 18 half-tones of pioneers in comparative psychology, and bibliographies aggregating 1,549 titles.

Chapter 1 provides an excellent history of the comparative psychology movement. Emphasis is placed upon the several currents of psycho-biological thought from which modern comparative psychology has emerged, and ideas rather than men are the key-notes. Chapter 2 digresses momentarily from the theme of the opening chapter to show why the fundamental tenets of vitalism and teleology are unsatisfactory for a thorough-going objective science of animal behavior. They are rejected in favor of a natural science point of view, the nature, scope, and aims of which are lucidly stated. Chapter 3 is concerned with biological foundations. It opens with a brief

account of the evolution of living systems and closes with a consideration of ontogenetic aspects of biology in which attention is given to the problems of individual inheritance, maturation, and behavioral adaptations through learning. Six and one-half pages are devoted to current theories of learning. In Chapter 4 one finds the authors rejecting the traditional classification of behavior as either native or acquired, a classification that rests upon the antithesis of heredity and environment and has as its principle of organization the genetic origins of responses. In place of the foregoing classification, they have substituted a duo-fold classification of activities that emphasizes the important life-functions, namely, the receptive and the reactive capacities. The latter part of Chapter 4 is devoted to a consideration of general methods of studying behavior, such as the experimental method, the genetic method, and the comparative method. Chapters 5 and 6, which are really inseparable, deal with instruments, techniques, and principles of methodology that now are recognized the world over as the stock-in-trade of animal psychology. Here above all the maturity and scholarly grasp of the authors are clearly indicated by their ability to deal adequately with origins and at the same time to feature those things that have been significant in the development of comparative psychology as a science. Illustrations are numerous and the zinco cuts are beautifully executed. The closing chapter of this volume is a brief but excellent introduction to the comparative anatomy and physiology of receptor and effector mechanisms.

This volume, entitled *Principles and Methods,* is to be followed soon by a two-volume survey of plant and animal behavior.

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FINNER, P. F., *An Introduction to Experimental Psychology.* New York: Prentice-Hall, Inc., 1935. Pp. xiii+268. VALENTINE, W. L., TAYLOR, J. H., BAKER, K. H., and STANTON, F. N., *Student's Guide for Beginning the Study of Psychology.* New York: Prentice-Hall, Inc., 1935. Pp. vii+267. CRAWLEY, S. L., *Study Outline for General Psychology.* New York: Prentice-Hall, Inc., 1935. Pp. ix+223.

These three volumes are designed, each in a different way, to meet the increasing demand for instructional aids in a beginning course in psychology. The demonstration of laboratory techniques, observation and participation in actual experiments, and the use of

workbooks are increasingly popular practices designed to increase the student's interest, comprehension, and respect for psychology. They also tend to standardize the work in such courses.

The first two of these books are more appropriate for courses in which a definitely scheduled portion of the class time is devoted to laboratory work, but many experiments from each manual may be selected for performance in lecture sections as helpful demonstrations for particular topics under discussion.

The book by Finner serves the dual purpose of text and laboratory manual. As a text it gives a very brief, though lucid, exposition of scientific psychology. It is intended as a basis from which its 54 experiments and the usual comprehensive lectures by the instructor will give a complete course in elementary experimental psychology.

The book is divided into three parts. First there is an expository part (20 pp.) on scientific method and the subject matter of psychology. Part II (96 pp.) provides discussions and instruction for 54 experiments covering the usual topics of experimental psychology. Part III (50 pp.) gives a very good introduction to elementary statistics. While, strictly speaking, this material is not psychology, it is fairly essential as a part of this course in schools where courses in statistical method are not given. Instruction and exercises are provided in the nature of objective records and their preparation, measures of central tendency, variability, correlation and reliability. It might be desirable to give Part III before Part II.

In Part II, 28 experiments are devoted to the problems of learning, memory, muscular action and control, and vision. The other usual topics are covered more briefly. The emphasis in Part III upon statistical method is well integrated with Part II, in which many of the experiments are designed to "impart knowledge of the subject to the subject and of the group to the group." Most of the experiments are followed by questions for written answers and discussion. A limited amount of apparatus is required, but laboratories which are well equipped could profitably demonstrate more apparatus in connection with some of the experiments.

An appendix of 85 pages provides key and data sheets for individual and group results.

The manual by Valentine *et al.* is closely integrated with Dockeray's *General Psychology* and Valentine's *Readings in Experimental Psychology,* but can be used easily in connection with any modern text. Instructions are given for 121 short experiments and

exercises. The exercises consist largely of tally questionnaires, rating scales, and descriptions of controlled observations which are designed to reveal certain psychological facts, often of a social nature, which may be readily treated objectively and statistically.

Valentine and his collaborators felt "that the supposedly more rigorous training formerly given in laboratory techniques was unsuited to the large majority . . . of students; that emphasis should be laid rather on the application of scientific method to the socially important problems of human behavior." Those who agree will find a great deal of material admirably suited to this kind of instruction. In the reviewer's opinion the experiments and exercises are stimulating to the student's interest and can be easily raised above the level of "busy work" by proper preparation and elucidation of scientific value on the part of the instructor.

"The exercises are grouped into units, each unit treating of some problem generally mentioned in the standard texts and comprising a convenient assignment." Eighty-two of the exercises may be classified under the topics of learning, memory, intelligence, thought, feeling and emotion, motivation, personality, and social reactions, while the remaining 39 exercises are concerned with sensation, perception, attention, muscular reaction, growth, and statistics.

Most of the demonstrations are not dependent upon apparatus, but the best use of the manual should require an ordinary amount of equipment for sensation and reaction work. The exercises on growth and genetic development depend largely upon three or four films.

This manual provides objective tests on certain work covered plus four technical vocabulary tests. Cumulative progress records and a spiral binding add to the value and usability to the student.

The outline by Crawley is a guide for study which aims to present the basic facts, theories, and values of psychology through brief expository discussions and exercises. It may be used as a corollary with any standard text and is well constructed physically and in content to suit the convenience of both student and instructor. The outline is adequately extensive for a year's course but may be easily condensed or abbreviated, without slighting essentials, for a semester course.

The exercises consist not merely of questions for thought or written answers but also of assignments for student performance. The treatment is purposely controversial, which should suit the tastes of those instructors who aim to interest the student in the expanding

nature of psychology as it evolves new facts and theories from controversy and experiment.

There are 13 sections corresponding to the usual chapter headings in texts. Each section is complemented with review questions and an extensive bibliography of both general text references and other special literature. (The general references average 35 per section and the other readings average 38 per section.) Controversial problems may be followed adequately through the bibliography with a certain amount of guidance by the instructor.

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BOOKS RECEIVED

CHASSELL, C. F., *The Relation Between Morality and Intellect.* T. C. Contr. to Educ. No. 607. New York: Bureau of Publications, Teachers College, Columbia University, 1935. Pp. xviii+556.

COLE, LUELLA, *Psychology of Adolescence.* New York: Farrar and Rinehart, 1936. Pp. xvi+503.

DOCKERAY, F. C., *General Psychology.* New York: Prentice-Hall, Inc., 1935. Pp. xxix+576.

DUNLAP, K., *Elements of Psychology.* St. Louis: The C. V. Mosby Company, 1936. Pp. 499.

Educational Directory, 1935. Washington: U. S. Department of the Interior, 1935. Bulletin No. 1. Pp. 168.

Graduate Theses. University of Iowa Studies, Series on Aims and Progress of Research, No. 49. Iowa City: University of Iowa, 1936. Pp. 61.

GRENSTED, L. W., *Psychology and God.* New York: Longmans, Green and Company, 1936. Pp. xi+275.

HALL, G. M., *Prostitution in the Modern World.* New York: Emerson Books, Inc., 1936. Pp. 200.

NOTES AND NEWS

SEVENTY-FIVE scientific men and scholars, including fourteen Nobel laureates, will meet for the Harvard Tercentenary Conference of Arts and Sciences at Harvard, August 31 to September 12, 1936. The Conference will include a symposium on human behavior on September 7. This part of the program will present the conclusions of eight workers in the fields of physiology, history, biochemistry, philosophy, education, anthropology and psychology. Professor Edgar D. Adrian, University of Cambridge, will open this symposium with a discussion of the influence of the nervous system on human behavior. *Psychological Factors* will be treated by Professor Carl G. Jung, Technische Hochschule, Zurich; *Hormones* by Professor James B. Collip, McGill University; *Logic* by Professor Rudolph Carnap, Deutsche Universität, Prague; and *Culture* by Professor Bronislaw Malinowski, University of London. At the same symposium, Dr. A. Lawrence Lowell, president-emeritus of Harvard University, will give *An Example from the Evidence of History;* Professor Pierre Janet, Collège de France, will tell of *La force et la faiblesse psychologique;* and Professor Jean Piaget, University of Geneva, will discuss *The Principal Factors Determining the Intellectual Evolution from Infancy to Adult Age.*—From *Science.*

THE eighth annual meeting of the Society of Experimental Psychologists was held April 9 and 10, 1936, at Clark University under the chairmanship of Professor Walter S. Hunter. Twenty members representing 14 laboratories were present and reported experimental work in progress for discussion. The next meeting will be held in the spring of 1937 at Smith College under the chairmanship of Professor Kurt Koffka.

AT THE meeting of the Society of Experimental Psychologists, the first award of the Howard Crosby Warren Medal was made jointly to Professor Ernest G. Wever and Dr. Charles W. Bray, of Princeton University, "for their studies of auditory nerve responses in reptiles and insects, following up their similar work on mammals, the whole research constituting an outstanding contribution to the study of auditory function." The medal was founded by Mrs.

Warren in memory of her husband, Professor Howard Crosby Warren, the first chairman of the Society of Experimental Psychologists and for many years professor of psychology at Princeton University. The medal is to be awarded annually by the society "for outstanding work in experimental psychology in the United States or Canada published during the five years preceding the time of the award."

DR. NORMAN L. MUNN, assistant professor of psychology at the University of Pittsburgh, has accepted a professorship of psychology at the George Peabody College for Teachers, Nashville, Tennessee. He succeeds Dr. Joseph Peterson, who died on September 20, 1935. Dr. Munn assumed his new duties early in February.—From *Science*.

DR. HARRY R. DESILVA has resigned as professor of psychology in charge of the psychological laboratory at the Massachusetts State College to join the staff of the Bureau for Street Traffic Research of Harvard University. He will conduct research on the constructive aspects of controlling the motor car driver.—From *Science*.